Social contracts for adaptation to climate change –

Conceptual contributions, methodological innovations, and empirical insights from flood risk management in Mumbai

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SUMMARY

Adaptation to the impacts of climate change is becoming increasingly urgent and challenging. Meeting the stark challenges of adaptation will require collective efforts from different actors of society (state, civil society, individuals, private sector, etc.), ideally with a shared understanding of adaptation goals and visions and a clear, agreed-upon distribution of roles and responsibilities. However, in reality, adaptation often occurs in a socially contested arena, characterized by multi-actor constellations with potentially diverging viewpoints on what different actors envision and expect in terms of adaptation priorities and the distribution of roles and responsibilities for adaptation. An urgent requirement to advance adaptation efforts is the need for coherent social contracts where actors ideally agree or find an arrangement, despite conflicting perspectives.

Despite the growing scientific research on adaptation, several gaps could be observed in the conceptual, theoretical, empirical, and methodological debates on understanding and assessing social contracts for adaptation in the current literature. Although previous literature has established the potential usefulness of a social contracts lens to adaptation debates, detailed conceptual and theoretical understanding in the adaptation context is largely lacking to date. Further, empirical evidence and conceptual literature on actors' desired adaptation objectives and perceived distributions of roles and responsibilities have received some attention yet remain under-researched and often without an explicit social contracts lens. Given such perspectives' tacit and implicit nature, a related methodological challenge is the difficulty in capturing actors' diverse viewpoints. A significant step toward achieving coherent social contracts for adaptation is understanding how different actors perceive and evaluate their solution spaces for adaptation in a multi-dimensional fashion, which has not received sufficient attention in the literature.

The above-identified gaps are most starkly illustrated in cities and urban areas, especially in countries with emerging markets, that are situated at the confluence of being on the frontlines of climate risk globally, faced with high adaptation pressure, changing patterns of social, economic, and demographic growth but at the same time also seen as frontrunners and role models of countries and regions. Mumbai, the financial capital of India, ranks among the top cities at risk of coastal flooding and the impact of rising sea levels in current and future rankings. The city is characterized by some of the heaviest adaptation challenges that one can find globally, along with stark inequalities, with almost half the population living in slums on the one end and a powerful elite on the other, with a growing aspirational middle class in between. Hence, the study draws on flood risk management in Mumbai, considered a highly relevant and important empirical case.

The study presented here aims to address the above-identified research gaps and adopts a three-fold objective. First, it seeks to advance the conceptual understanding of social contracts for adaptation by providing a framework to guide their assessment. Second, it aims to empirically assess how different actors perceive and evaluate adaptation solution spaces for their desirability and feasibility in a multi-dimensional fashion. Further, the study assesses actors' desired adaptation objectives and expectations on the distribution of roles and responsibilities for adaptation to flood risk in Mumbai. Finally, in methodological terms, it aims to explore the potential of using social listening on Twitter to assess social contracts for adaptation in cities and other societal contexts.

Against this background, the study adopts a mixed methods approach and combines inductive exploration of the data with the deductive application of a social contracts theoretical lens. The study

develops the approach of social listening using Twitter data to capture actors' diverse viewpoints on adaptation priorities and expectations of roles and responsibilities for flood risk management in Mumbai, given that social media platforms are becoming increasingly important arenas of exchange. This involved collecting all flood-risk-related Tweets over four months of the monsoon season 2021 (ca. 70,000 Tweets), which were subsequently filtered for their dominance and analyzed. These findings are triangulated with semi-structured expert interviews conducted with key stakeholders across the state, civil society, and academic actors from Mumbai and field-based participant observation at workshops and meetings. The initially planned household survey had to be postponed due to the pandemic that heavily influenced the research design of this study.

Guided by the conceptual lens of social contracts and the mixed-methods approach, the study draws on the empirical analysis of flood risk management in Mumbai. The findings from the multi-dimensional evaluation of perceived solution spaces for adaptation revealed significant mismatches between state and non-state actors' perceptions of desirability and the evaluation of the feasibility of different adaptation options. Overall, institutional changes and the pivotal role of institutional dimensions were most strongly identified, especially by non-state actors. At the same time, the starkest disparities were found between state and non-state actors on physical infrastructure measures. In operationalizing the conceptual framework of social contracts for adaptation, the study found surprisingly wide gaps and large contestations in the adaptation debates in Mumbai in two respects: between different actors and between what actors envisioned, observed in reality, and perceived as legally defined. Diverging viewpoints on actors' desired adaptation objectives and target actors could be observed as well as strong rifts in the distribution of roles and responsibilities. In addition to the diverging perspectives, the findings also showed ambiguity in both regards, where actors did not clearly articulate their views. Social listening on Twitter allowed to capture actors' unsolicited, implicit, and tacit viewpoints in a large N sample in almost real-time. Further, the qualitative sentiment analysis proved to be a helpful entry point for understanding the gaps between actors' viewpoints and expectations.

The study could make an empirical and analytical contribution to advance current feasibility assessments of adaptation options by including an actor-specific lens, distinguishing desirability from feasibility, and applying it to real-world settings. An explicit focus on actors' desired adaptation objectives and target actors and the contestations revealed through the empirical findings emphasize the importance of assessing and aligning actors' underlying priorities in negotiating the process of forming coherent social contracts for adaptation. The findings suggest aligning actors' desired adaptation objectives as a first step toward shaping coherent social contracts for adaptation. Rifts and ambiguities in actors' perceptions of who is or should be responsible for what tasks in adapting ultimately have severe implications on the distribution of burdens. These questions become critical when existing risk management regimes start to approach their limits not only in light of the changing feasibility or effectiveness of adaptation options but also in the face of evolving priorities in rapidly growing economies and aspirational societies such as India. The study's most novel contribution lies in its methodological development of social listening on Twitter to assess gaps in social contracts for adaptation. The study could contribute to the conceptual, empirical, and methodological realms of scientific knowledge on social contracts for adaptation and propose several questions for future research.

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1. INTRODUCTION

1.1 Research background

The impacts of climate change are increasingly affecting humans and ecosystems worldwide. Adaptation efforts are crucial to reducing climate-related risks (Ara Begum et al., 2022). Given the uneven distribution of risks, vulnerabilities, and adaptive capacities – socially, spatially, and temporally, there is no "one size fits all approach" to adaptation (Hansen & Bi, 2017). Studies have identified a wide range of adaptation options, e.g., physical infrastructure, ecosystem-based measures, social measures, and institutional measures, thereby underlining the diversity of approaches that will be required depending on the context, scale, different hazard types, sectors, and stakeholders (Ara Begum et al., 2022; Noble et al., 2014). A growing evidence base on the tracking of adaptation progress at the global, regional, national, and local levels shows that people and institutions are taking measures to adapt to the impacts of climate change (Araos et al., 2021; Berrang-Ford et al., 2021; Garschagen et al., 2021; Lesnikowski et al., 2016; Olazabal et al., 2019). Yet, the latest Sixth Assessment Report of the Intergovernmental Panel on Climate Change (from here on referred to as IPCC AR6) indicates that societies currently face more than ever high pressure to adapt and in many respects are already confronted with an 'adaptation deficit' or inadequate adaptation to the current impacts of climate change (IPCC, 2022a). Moreover, with the impacts expected from climate change in the future to be so pervasive, societies will be required to step up their adaptation efforts significantly, which might call for transformative shifts in how they adapt and manage the risks associated with climate change (O'Brien, 2012; Pelling et al., 2015).

Cities, in particular in low-lying coastal areas in the Global South, are faced with heavy adaptation challenges as they are often at the frontlines of climate hazard exposure and at the same time confronted with pressures of urbanization such as high path dependencies from past urban infrastructures, protection of ecosystem services, social and economic inequalities associated with poverty, limited institutional capacities to deal with risk management and challenging access to funding (Dodman et al., 2022a; Garschagen & Romero-Lankao, 2015; Rosenzweig et al., 2018). At the same time, many of these cities, such as Mumbai, Jakarta, Manila, and Ho Chi Minh City in South and Southeast Asia, are also centers of great economic and political attention and present opportunities for risk reduction (World Risk Report 2014). Despite the documented progress in adaptation so far, the literature points to significant adaptation gaps that persist, owing to reasons such as a lack of sense of urgency, low political willingness for action, and uncertainties about the future developments of climate change (de Coninck et al., 2018; IPCC, 2022a; United Nations Environment Programme, 2023). Hence, understanding how societal adaptation can be fostered, especially in cities and urban areas, is becoming increasingly important and urgent.

Adapting to the unprecedented impacts of climate change poses new challenges to existing risk management regimes. It is well established in the literature that adaptation involves several actors at different levels of social organization – such as the state, businesses, civil society, households, and individuals (Petzold et al., 2023). Meeting adaptation challenges will, therefore, require collective efforts from different actors of society – ideally with a shared understanding of common adaptation goals and a clear distribution of roles and responsibilities (Adger et al., 2013a; Mees et al., 2012). In

reality, multi-actor constellations are often characterized by conflicting viewpoints on societal adaptation goals or what roles and responsibilities actors ascribe to other actor groups or themselves (Doshi & Garschagen, 2023a; Ommer et al., 2024). This might lead to the question of whether current risk management paradigms, including measures and distributions of roles and responsibilities, will be sufficient or if societies are required to rethink, revisit, and renegotiate their adaptation priorities and distribution of roles and responsibilities. (Garschagen et al., forthcoming; Solecki et al., 2017).

Essential questions for societies in this regard are to clarify what adaptation futures are envisioned, whose futures are secured, and how the tasks to achieve these futures are distributed (Blackburn & Pelling, 2018; Hayward & O'Brien, 2010). Understanding the underlying objectives, priorities, and for what purpose adaptation is undertaken and for whom has important implications for assessing successful adaptation (Adger et al., 2005; Singh et al., 2022). Previous research suggests that ambiguous roles and unclear responsibilities, especially coupled with overambitious goals or with an emphasis on high-risk scenarios, would allow "difficult problems to shift to the backburner" (Christoplos et al., 2017, p.462). Rifts and ambiguities in roles and responsibilities have been identified as significant barriers in adaptation governance (Azhoni et al., 2017; G. R. Biesbroek et al., 2010; Garschagen, 2016; Lee et al., 2022). This has raised the crucial questions of 'who has what role and who is responsible for what' in the challenge of adapting to the impacts of climate change (Juhola, 2019; Mees et al., 2012; Petzold et al., 2023; Reckien & Petkova, 2019). For example, who is responsible for bearing the costs associated with damages to property due to a heavy flood event if insurance is no longer available or affordable in some flood-prone regions? Hence, it is becoming increasingly urgent for societies to negotiate the kind of adaptation futures they want and the roadmap, i.e., the distribution of roles and responsibilities, in getting there. However, this understanding is largely lacking to date, especially in cities and urban settings where heterogeneous social groups and their viewpoints might clash.

In consideration of the questions raised above about the definition of societal goals for adaptation and clarification on the distribution of roles and responsibilities between different actors to achieve them, the notion of 'social contracts' has been suggested in the adaptation literature. A social contracts lens has been argued for as a mechanism to explicate the politics of adaptation and provide an organizing framework for effective, legitimate, and collective responses to the challenges of climate change (Adger et al., 2013b; Blackburn & Pelling, 2018; Christoplos et al., 2017; Hayward & O'Brien, 2010). Social contracts can be a tacit or explicit agreement between state and non-state actors on reciprocal rights and responsibilities (Weale 2004). However, precisely the tacit and often implicit nature of such perceptions on adaptation goals and expectations regarding the distribution of roles and responsibilities also presents methodological challenges in capturing them. Hence, underlining the urgent need for exploring novel methods that allow capturing and understanding social contracts, especially given implicit or tacit viewpoints such as normative expectations.

The unique values offered by a social contracts lens to the questions of climate change adaptation in the context of this dissertation involve: First, its combined focus on societal adaptation goals and the distribution of roles and responsibilities to achieve them, hence allowing a better understanding of the underlying contestations and ambiguities and their potential linkages. Second, attention to actor perspectives across the above questions by asking 'adaptation for whom' and 'adaptation by whom' as perceived by different actors, thereby raising key concerns of fairness in adaptation and just risk

governance (Blackburn & Pelling, 2018; Hayward & O'Brien, 2010). Finally, it provides an organizing framework and language to describe and assess if and how the negotiation and renegotiation of potentially diverging viewpoints between different actors of society take place in response to the existing and emerging challenges of adapting to climate change.

The need for coherent, explicit social contracts for adaptation, in which actors agree on common adaptation goals and a clear distribution of roles and responsibilities, is most starkly visible in cities. Conflicting viewpoints on which adaptation goals should be pursued and how roles and responsibilities to achieve them are to be distributed might often arise in cities because of the convergence of diverse societal groups with varying socio-cultural backgrounds, economic and political interests, power imbalances, and different levels of risk acceptability (Krueger et al., 2022). These tensions might be revealed while addressing questions of political feasibility, economic development pressures on ecosystems, spatiotemporal trade-offs, whose futures are protected, and who bears the burden of the impacts (Chelleri et al., 2015).

A significant step on the way toward informing the negotiation of coherent social contracts is understanding how actors evaluate different adaptation options (Doshi & Garschagen, 2023b). Societies will be required to design context-specific risk management portfolios by selecting from an array of available adaptation options or also called the "solution space" (Haasnoot et al., 2020; Sainz de Murieta et al., 2014). Prioritization of adaptation options becomes important due to potential constraints such as a lack of resources or capacities that might inhibit the implementation of all available adaptation options (IPCC, 2014). For example, the lack of adequate funding for adaptation in many vulnerable countries is constraining their solution space to adapt, even if, from a geophysical, institutional, or technical perspective, adaptation options are available (Doshi & Garschagen, 2020; Garschagen & Doshi, 2022). In the process of selecting the most appropriate combinations of risk management measures, it becomes important to understand how different dimensions, e.g. geophysical, political-institutional, social, cultural, environmental, economic, and technological, influence the solution space for adaptation – now and in the future (Du et al., 2022; Haasnoot et al., 2020). Solution spaces are socially constructed and contested in nature, as different actors might view and evaluate various options differently (Haasnoot et al., 2020). Previous research suggests that the solution space is where diverging viewpoints and priorities can be resolved towards forming just adaptation pathways (Nursey-Bray, 2017). Hence, understanding how different actors evaluate potential adaptation options is essential for forming a coherent social contract.

To inform the process of shaping coherent social contracts for adaptation to climate change, it is therefore important to first, lay open and make explicit the often tacit or implicit viewpoints of different actors on perceived adaptation goals as well as the distribution of roles and responsibilities to achieve them. Second, to identify where potential gaps and contestations, as well as synergies, overlaps, and agreements, might lie. Third, assess if and how actors in cities and other social contexts negotiate potentially diverging viewpoints. Finally, to examine whether and how they settle at an arrangement which helps to moderate unresolvable gaps in expectations and ideally arrive at a shared vision on what adaptation goals should be pursued and how responsibilities for adaptation should be distributed (Doshi & Garschagen, 2023a).

Against this background, this study aims to assess social contracts for adaptation in the context of cities and in doing so, provide a conceptual framework to guide the operationalization of social

contracts and explore a novel methodological approach in capturing potential gaps in social contracts.

1.2 Research gaps

This section turns more closely to the specific context of this study by describing identified research gaps that limit the current understanding and fuller application of a social contracts lens for adaptation in cities and beyond. These gaps serve as the motivation and rationale for developing the research questions and thereby defining the scope of this study.

First, despite the usefulness of a social contracts lens to adaptation debates, the first observed gap relates to a lack of conceptual and theoretical literature on social contracts for adaptation that can guide empirical assessments. While the origins and development of social contracts theory can be traced back to the 17th and 18th centuries, their application and use in the context of climate change adaptation and related fields of disaster risk reduction, resilience, and sustainability has been relatively recent and in a limited number of studies, such as the works of O'Brien et al. (2009), Hayward & O'Brien (2010) and Adger et al. (2013b), to newer contributions by Blackburn & Pelling (2018), Siddiqi & Blackburn (2022), Krause et al. (2022) and Ommer et al. (2024), among others. Previous literature has made important contributions in invoking the concept of social contracts and arguing for its relevance and presumed gains that it would hold for knowledge generation and informing decision-making in climate change debates (ibid.). Blackburn & Pelling (2018) argue for a research agenda on social contracts for adaptation by providing a framework in response to the challenges of classical contractarian theory. However, the term 'social contract' in adaptation debates has been mostly used as a metaphor, loosely defined, and remains little conceptualized, especially to guide operationalization and empirical application for assessment in the adaptation context. The latest IPCC assessment report, which draws on current literature, does not explicitly refer to social contracts for adaptation. Hence, the concept has gained little traction up until now. A conceptual framework that guides the operationalization and empirical application for an assessment of social contracts is largely lacking to date.

Second, closely linked to the first gap, is an emerging research gap and the consequential need to assess goals and objectives for adaptation. Both directly and indirectly related to adaptation goals is the growing literature on the assessment of the effectiveness of adaptation (Owen, 2020; Reckien et al., 2023; Singh et al., 2022; Tubi & Williams, 2021), albeit without an explicit reference to social contracts. Assessments of effectiveness often refer to the intended outcomes of adaptation measures. In other words, an outcome refers to the adaptation goal that is to be achieved through the implementation of the selected measure(s) (Donatti et al., 2020). Previous studies have proposed guiding principles, frameworks, and methods to identify and assess adaptation outcomes and effectiveness. However, studies have noted the challenges posed to examining effectiveness due to the lack of agreed metrics, contested approaches, highly contextual nature of adaptation, and consideration of spatiotemporal trade-offs (Dilling et al., 2019; Eriksen et al., 2021; Magnan et al., 2020; Stadelmann et al., 2011). While studies have largely drawn on literature reviews in the assessment of the effectiveness of adaptation options (Chausson et al., 2020; Owen, 2020; Reckien et al., 2023; Singh et al., 2022), noting the socially contested and context-specific nature of adaptation, calls for the integration of actor perspectives in understanding which adaptation objectives are aimed for in the first place, and second, for whom they are intended to benefit by

different actors. For example, a seawall might be perceived as a successful adaptation intervention by a state actor if the goal that is to be achieved is maximizing efficiency for the state. However, the same measure might be perceived as maladaptive by a civil society actor, if the goal is to secure the livelihoods of the fishing communities living along the coast. Hence, engaging with actor-oriented/defined adaptation objectives and making explicit for whom they are intended is of high importance for driving just and equitable adaptation.

Third, there is a growing literature on understanding the roles and responsibilities of different actors for adaptation that forms the core of adaptation governance debates. Despite the lack of an explicit mention or linkage to the concept of social contracts, the findings from studies are of high relevance to informing coherent social contracts for adaptation (Juhola, 2019; Mees et al., 2012; Nalau et al., 2015; Persson et al., 2021; Petzold et al., 2023; Reckien & Petkova, 2019; Schneider, 2014). Previous literature has pointed to the challenges of ambiguous or conflicting roles and responsibilities in adaptation governance, thereby underlining the importance of making explicit actors' roles and responsibilities for adaptation. Prior studies have made major contributions in terms of conceptual frameworks, assessing typologies of responsibilities, and the underlying considerations in the allocation of responsibilities. While most literature has focused on empirical observations of 'who is playing what role', the normative distribution of roles and responsibilities i.e. 'who should play what role' is often unclear. A significant gap waiting to be filled in this regard is the perceived or expected distribution of roles and responsibilities for adaptation. This question is often fraught due to the challenge of how to capture the expectations on the distributions of roles and responsibilities due to their tacit and implicit nature. Nevertheless, identifying and capturing these gaps is an important prerequisite for closing these gaps.

Fourth, linked to the previous gaps, remains a methodological challenge in capturing and assessing the implicit and tacit social contracts that relate to the envisioned or desired adaptation goals and expected or normative understandings of who should be responsible for what. While previous studies have drawn on surveys and interviews to understand perceived roles and responsibilities (Mees et al., 2012; Reckien & Petkova, 2019), an important question remains: how can the exchange of opinions and negotiations of roles and responsibilities for climate change adaptation among different actors such as state, civil society, individuals and the private sector be inductively captured and assessed? Social media offers an important platform in this regard, often acting as a "digital town square" (Burgess, 2022). In the age of digitalization, Big Data and AI, social media platforms have several advantages for urban adaptation research e.g. volume, speed of data collection, and scale. Rapidly expanding literature on the use of different types of Big Data, including social media data in the field of climate change has drawn on both quantitative and qualitative methods. These include machine learning, Natural Language Processing techniques, content analysis, among others (Cody et al., 2015; Eslen-Ziya, 2022; Kirilenko et al., 2015; Roberts et al., 2019). However, previous studies crucially highlight that Big Data, including social media data, offers significant potential to contribute context-specific insights, yet, has been heavily underutilized, especially in combination with qualitative methods to capture "contextual complexity" (Ford et al., 2016; Ilieva & McPhearson, 2018). Hence, the potential of social media data to capture and assess social contracts has not yet been explored.

Fifth, the literature has made significant progress in assessing the strengths and weaknesses of different adaptation options under concepts such as feasibility, effectiveness, readiness, barriers,

and enablers to adaptation. Feasibility assessments of adaptation options have been few. This is primarily owed to the large yet highly context-specific evidence of adaptation, lack of data on different dimensions influencing feasibility, and disagreement on the metrics (Singh et al., 2020). However, there have been few comprehensive feasibility assessments of adaptation options in certain regions, e.g. on adaptation-related responses in Africa (Williams et al., 2021) and in certain sectors, e.g. in agriculture (Thornton et al., 2018) and (Zobeidi et al., 2024), and in the water sector (Singh et al., 2020). A significant methodological advancement in the feasibility assessment of adaptation options by (Singh et al., 2020) goes beyond previous assessments that treated feasibility as a binary or evaluated adaptation options using traditional cost-benefit analyses (das Neves et al., 2023; de Bruin et al., 2009; Devkota et al., 2017; Hallegatte, 2011). This approach of multi-dimensional feasibility assessment of adaptation options has been particularly useful in synthesizing evidence on adaptation across big literature and has been applied in the IPCC's Special Report on 1.5C and the latest Sixth Assessment report (IPCC, 2018a, 2022b). Yet, such multi-dimensional evaluations have largely focused on individual adaptation measures and drawn on available literature to aggregate the information on their feasibility dimensions. What has been largely missing from these evaluations is how different actors evaluate different adaptation options in specific contexts. Given the socially constructed and contested nature of adaptation solution spaces, it becomes important to understand actor-specific views on the pros and cons of different measures, or in other words, 'perceived solution spaces' (Doshi & Garschagen, 2023b; Haasnoot et al., 2020). Negotiating such potentially diverging viewpoints and designing portfolios of risk management measures will involve difficult choices to be made. These might include, for example, whose interests to prioritize, which trade-offs to make, where could be potential synergies but also conflicts – all of which might change over time. In doing so, an actor-oriented assessment would also allow going beyond most feasibility assessments that integrate the aspect of desirability into feasibility, whereas studies show that actors often perceive and evaluate options differently for desirability and feasibility (Dawson et al., 2016; Lemieux & Scott, 2011).

The study aims to address the above gaps by empirically drawing on the case study of flood risk management in Mumbai, the financial capital of India, and globally ranks among the top 10 coastal megacities at risk to flooding (Nicholls et al., 2008). Mumbai makes an apt case study for understanding and assessing social contracts for adaptation for two main reasons:

First, the city is characterized by some of the highest adaptation pressures that can be found due to its risk profile. Mumbai is at high risk to flooding – not only due to heavy rainfall events that are a common feature of the annual monsoon season, but also due to rapidly changing exposure patterns driven by land reclamation, soil sealing, and destruction of ecosystems. The city also faces high socio-economic vulnerability, especially for almost half of the population that lives in informal settlements, often with uncertainty of tenure, limited access to basic civic infrastructure and suffer disproportionately high impacts, e.g. on health and livelihoods (Adam et al., 2021; Butsch et al., 2016).

Second, the landscape of risk management is heavily contested, and the city is confronted with complex challenges to adaptation (Movik et al., 2023; Parthasarathy, 2016c; Zimmermann et al., 2023). Mumbai is characterized by stark inequality – while almost half of the population is highly vulnerable, it also has a small yet powerful elite and a growing influential middle class that results in the power asymmetries shaping the political economy of the city (De Sherbin & Bardy, 2016; Texier-Teixeira & Edelblutte, 2017). As the financial capital of India - the world's fifth largest economy, the

economic development has been a major driver of its rapid urbanization (David, 2019). At the same time, the confluence of increasing impacts of climate change will necessitate difficult trade-offs between competing interests and values in risk management.

How the city adapts to the impacts of climate change, whose lives and livelihoods are protected, and how the roles and responsibilities for the challenging tasks of adaptation will be distributed, will play a crucial role in the future of Mumbai. Hence, focusing on the case study of Mumbai, addresses a further empirical gap of understanding and assessing social contracts for adaptation in the context of urban settings.

In view of the above identified gaps, the following section outlines the main objectives and research questions of this study.

1.3 Research objectives and questions

Against the background and motivation to address the gaps described above, the study has a three-fold objective:

First, on a conceptual and theoretical level, the study aims to define coherent social contracts for adaptation and put forward a conceptual framework for understanding and assessing social contracts for adaptation. The framework aims to do two things: one, guide the empirical assessment of social contracts for adaptation in this study and potentially future research; two, inform the process of the formation of *coherent* social contracts for adaptation.

Second, in empirical terms, the study aims to operationalize the framework and apply it to the case of flood risk management in Mumbai. In doing so, it aims to understand how different actors evaluate adaptation solution spaces, identify which adaptation objectives (and for whom), and perceive who to play a role and be responsible for what in adapting to flood risk in Mumbai.

Finally, methodologically, the study explores and develops a novel approach to assess social contracts for adaptation by using social listening through Twitter – an increasingly important arena for capturing the exchange of different actors' viewpoints. The study aims to contribute to the advancement of multi-dimensional evaluations of perceived solution spaces for adaptation by providing a heuristic framework to guide empirical assessments.

Aligned with the research objectives of this study, the dissertation aims to answer the following questions, each of which has a center of gravity in terms of its conceptual, empirical or methodological objectives but also aims to provide feedbacks into one or the other objectives.

RQ 1. How can social contracts for adaptation be defined and conceptually framed to guide their assessment?

RQ 2. How do actors evaluate their 'perceived' solution spaces for adaptation to flood risk in Mumbai in terms of their feasibility and desirability?

RQ 3. Which objectives do actors aim to achieve through the above identified adaptation options and for which target actors are they intended?

RQ 4. What roles and responsibilities do actors expect from other actors and themselves for adaptation to flood risk in Mumbai?

RQ 5. How does social listening contribute to capturing and assessing social contracts?

Given the cumulative nature of this dissertation, the above research questions and objectives are addressed in a cross-cutting manner in three core peer-reviewed publications comprising this study.

Table 1 | Core publications and their contributions comprising this cumulative dissertation

	Publication I	**Publication II**	**Publication III**
Title	Assessing social contracts for urban adaptation through social listening on Twitter	Ruptures in perceived solution spaces for adaptation to flood risk: Heuristic insights from Mumbai and general lessons	Actor-specific adaptation objectives shape perceived roles and responsibilities: Lessons from Mumbai's flood risk reduction and general considerations
Main contribution	-Conceptual: Framing social contracts and their types and dimensions Methodological: Using social listening on Twitter to assess social contracts -Empirical: Insights on gaps between different dimensions of social contracts through sentiments	-Conceptual: Evaluation framing of perceived adaptation solution spaces -Empirical: Insights on actor-oriented evaluations of adaptation options for feasibility and desirability criteria in Mumbai	-Conceptual: Influence of actors' objectives on perceived roles and responsibilities -Empirical: Insights on desired objectives and perceived roles and responsibilities for flood risk reduction in Mumbai
Authorship	Doshi, D. and Garschagen, M.	Doshi, D. and Garschagen, M.	Doshi, D. and Garschagen, M.
Status	Published (05. June 2023)	Published (05. July 2023)	Published (29. October 2024)
Journal	Nature Partner Journal (npj) Urban Sustainability	Climate Risk Management	Regional Environmental Change
Impact Factor	N.A. (No IF yet; started publishing in 2021)	6.1	4.9
Addressed Research Questions*	RQ 1, 4 and 5	RQ 1 and 2	RQ 1, 3 and 4
Section in this dissertation	5.1	5.2	5.3

*Corresponds to research questions in Section 1.3

Table 1

Table 1 maps out the three articles and the corresponding research questions that they address.

The contributions highlighted above can be viewed as relevant and novel because they offer a unique perspective and innovative approach to understanding, capturing, and assessing social contracts for adaptation, which has so far gained little attention in urban adaptation and risk research, despite the presumed usefulness that such a lens would bring for shaping coherent societal adaptation debates. Adaptation to the impacts of climate change, both current and future, will inevitably lead to questioning societal adaptation goals and the distribution of roles and responsibilities, leading to implicit or explicit shifts in the same. This study's contribution to social contracts for adaptation aims at sharpening the conceptual and analytical lens in making them explicit to inform the negotiation (or renegotiation) towards forming coherent social contracts for adaptation. The novelty of this study lies in its methodological approach of using social listening on Twitter to capture and assess social contracts for adaptation – an approach and database that has been heavily underutilized in adaptation research. Finally, given the deep institutional changes that will be required for societies to adapt to the impacts of climate change, the study's contributions to social contracts can be considered of high relevance (Kuhl et al., 2021; Patterson & Huitema, 2019; Romero-Lankao et al., 2016; Rosenschöld & Rozema, 2019).

Addressing these questions is crucial not only for enhancing scientific debates on adaptation but also because they hold significant relevance for policymaking. The urgency and necessity to understand and evaluate the progress in adaptation stems from the first global stocktake and the related Global Goal on Adaptation (Article 7.1) mandated by the Paris Climate Agreement (UNFCCC, 2015). It aims to assess adequacy and effectiveness of adaptation and thereby calls on countries to report on their progress on adaptation. Conceptual debates on social contracts for adaptation will be key in the complex challenge of understanding, conceptualizing and operationalizing the Global Goal on Adaptation. With adaptation finance expected to play a key role in achieving adaptation goals, especially for the most vulnerable countries, questions of whose adaptation futures are protected and how the costs should be distributed will become increasingly important. These challenges are also reflected at the national level, e.g. in countries' formulation and implementation of National Adaptation Plans or at the local level.

1.4 Research contributions beyond this dissertation

Beyond the contributions of this dissertation, I contributed to ongoing adaptation debates through additional scientific publications on the above topics. I actively involved myself in research endeavors such as the Global Adaptation Mapping Initiative (GAMI), tracking adaptation finance, understanding future risk and vulnerability trends in national adaptation planning, and assessing vulnerability using index-based approaches. Table 2 outlines these additional contributions in the form of five peer-reviewed publications.

Table 2 | Other contributions to climate change adaptation debates during this study

	Title of Publication	Authorship	Journal	IF 2022 (5Y)	Date of publication	Personal contribution
1	Does funds-based adaptation finance reach the most vulnerable countries?	Garschagen, M. and **Doshi, D.**	Global Environmental Change	13.0	10. January 2022	Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization
2	The consideration of future risk trends in national adaptation planning: Conceptual gaps and empirical lessons	Garschagen, M., **Doshi, D.,** Moure, M., James, H., Shekhar, H.	Climate Risk Management	6.1	13. October 2021	Data analysis, data visualization, co-authored the manuscript
3	A systematic global stocktake of evidence on human adaptation to climate change	Berrang-Ford, L., … **Doshi, D.**, … et al.	Nature Climate Change	31.4	28. October 2021	Coding of literature on urban adaptation progress, commented on the final manuscript
4	Global patterns of disaster and climate risk—an analysis of the consistency of leading index-based assessments and their results	Garschagen, M., **Doshi, D.**, Reith, J., Hagenlocher, M.	Climatic Change	5.3	12. November 2021	Data collection, data visualization, co-authored the manuscript
5	Understanding Adaptation Finance Allocation: Which Factors Enable or Constrain Vulnerable Countries to Access Funding?	**Doshi, D.** and Garschagen, M.	Sustainability (Special Issue on Climate Finance)	3.9	25. May 2020	Conceptualization, Data curation, data analysis, Interpretation, Visualization, Drafting of manuscript

Table 2

2. CONCEPTUAL AND THEORETICAL EMBEDDING

Having laid the groundwork for the broader motivations and rationale for the study, this chapter will delve into the theoretical and conceptual underpinnings that guided this dissertation. This study sits at the interface of different streams of scholarship such as human geography, disaster risk research, climate studies, urban geography, and risk governance. The overarching concepts of risk, vulnerability, and adaptation conceptually steer the topic of this dissertation. The first section (2.1) provides a concise overview of these concepts and key aspects essential for the scope of this study. The second section (2.2) reviews key theoretical elements of social contracts and attempts to provide a concise, but by no means exhaustive, review of relevant literature on the application of social contracts in adaptation and related fields. The third section (2.3) outlines the relevance of using cities as a unit of analysis in this study and the importance of focusing on social contracts for urban adaptation. Finally, the chapter concludes by providing an own conceptual framing on social contracts for adaptation that guides this study (2.4).

2.1 Conceptualizing risk and adaptation

2.1.1 Concepts of risk and vulnerability

The concepts of risk and vulnerability developed over four decades of research are central to guiding this dissertation in the context of urban adaptation to flood risk. This study adopts a vulnerability lens because it marks a paradigmatic shift in the understanding of risks and disasters as determined not by natural hazards only (a key tenet of the Dominant View), but also by social, economic, cultural, and political structures, factors, and processes that generate socially and spatially stratified vulnerabilities. This shift, starting in the mid-1970s, came as a response to the critique of the Dominant View (succinctly captured in the seminal works of Hewitt (1983) and O'Keefe et al. (1976). Despite the critiques of the Dominant View and its hazard-centric focus, it is important to acknowledge the influence it had on science, practice, policy-making, and resource allocations to risk reduction approaches that focused on controlling or 'taming' the natural environment through physical and structural engineering-based response measures (Handmer, 2003; Hewitt, 1983) – often described as the technocratic approach or technological fix to risk reduction. The 'Dominant View' paradigm leads to question its influence and implications on risk management measures in the context of flood risk management in Mumbai that try to 'tame' the hazard event through physical infrastructure and engineering-based measures (cf. 4.2). This aspect is particularly explored in the second paper of this dissertation on the evaluation of the adaptation solution spaces for flood risk management in Mumbai (cf. 5.2).

The essence of this paradigm shift from a hazard-centric focus to vulnerability thinking has been to explicate and understand the relationship between humans and the environment (Cannon, 1994). This was followed by many conceptual frameworks and advancements in understanding risk and vulnerability, starting with the fundamental risk equation by Blaikie et al. (1994) – Risk = Hazard x Vulnerability, the Pressure and Release model (Blaikie et al., 1994), Bohle's double structure of vulnerability (Bohle, 2001), the Turner framework (Turner et al., 2003), the MOVE framework (Birkmann et al., 2013), etc. which all have different definitions of vulnerability. Vulnerability remains a contested concept, yet an important one in bringing different communities – development

geography, disaster risk, and climate change adaptation together. This study adopts the IPCC's risk framework (IPCC, 2014). The IPCC risk framework is chosen because it conceptualizes risk as a function of the interaction of hazard, exposure, and vulnerability, in contrast to previous frameworks that considered exposure as a sub-component of vulnerability (Birkmann et al., 2013; Bohle, 2001; IPCC, 2007; Turner et al., 2003). This distinction allows for a sharper analysis of the impacts of adaptation measures on risk reduction, especially in terms of reducing exposure and vulnerability.

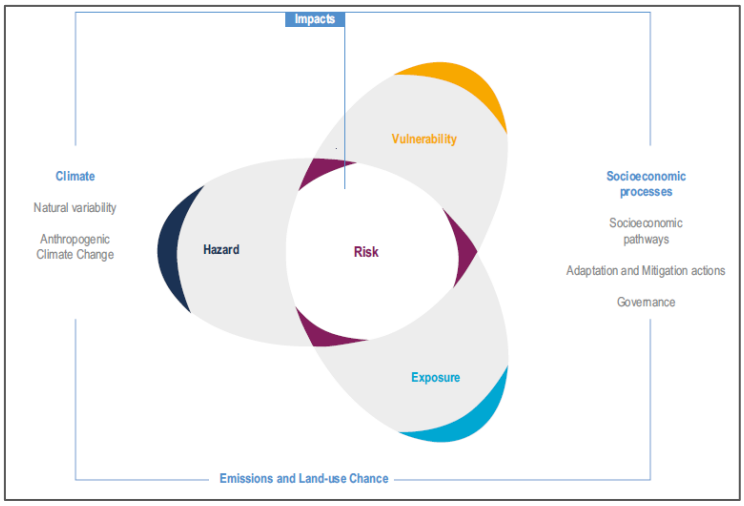


Figure 1: The IPCC AR5 risk framework, source: IPCC 2022

Risk is understood as "The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems." (IPCC, 2022a, p. 2921). For the context of this dissertation, risks from the impacts of climate change are defined as resulting from "dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards" (ibid.). Hazard is defined as "The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (ibid, p.2911)." Exposure is understood as "The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected." (ibid., p. 2908). Following the IPCC, vulnerability in this study is defined as "the propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022b, p.133).

2.1.2 Conceptualizing adaptation

This conceptual understanding of risk and vulnerability forms the core rationale for focusing on adaptation as the mechanism for reducing risk. The concept of adaptation has significantly advanced in the literature, starting from its origins in evolutionary biology to its current application in the context of climate change. This study adopts the IPCC's definition of adaptation where adaptation refers to "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (IPCC, 2022a, p.2898). Smit et al. (2000)'s "An anatomy of adaptation to climate change and variability", draws attention to the key characteristics of adaptation. The first question – "adaptation to what" involves consideration of the stimuli to

which adaptation is needed, whether it is climate-related or even associated with non-climatic factors and processes such as institutional or economic changes This study focuses on adaptation to flood risk in Mumbai, driven not only by hazard-related physical aspects but also by social, economic, political, and cultural factors and processes. (cf. 4.1 for context-specific drivers of flood risk in Mumbai). Furthermore, adaptation can be undertaken in response to adverse impacts or in anticipation of exploiting opportunities. The question "who or what adapts" could refer to people, sectors, ecological systems, structures, or processes. Understanding this question is important because differences in vulnerability and adaptive capacity of "who adapts" or "for whom" adaptation is planned or targeted, influence the design, implementation, and evaluation of adaptation measures. Adaptive capacity is defined as "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences"(IPCC, 2022a, p.2899). The question "how does adaptation occur?" emphasizes two characteristics of adaptation – first, it can be both a process or outcome and second, it could occur autonomously or spontaneously as well as be strategically planned It could also occur in a mixed way, where both autonomous and planned adaptation both interact (Shukla et al., under review). Taken together, these questions inspire the guiding questions developed for the operationalization of social contracts for adaptation (cf.2.4).

Having defined the concepts of risk and adaptation, Table 3 outlines the relationship of key aspects of risk to adaptation that are relevant for this study.

Table 3 | Relationship between key aspects of risk, vulnerability, and adaptation

Characteristics of risk and vulnerability	Relation to adaptation
Multi-dimensional: Risk is driven by hazard, exposure, and vulnerability. Vulnerability is multi-dimensional, and co-produced by social, political, cultural, and economic factors and processes.	This nature of risk and vulnerability informs the understanding of how adaptation measures aim to reduce risk. It also suggests the need for a portfolio or range of diverse adaptation measures and together, the need for multi-dimensional evaluations of adaptation options in terms of their feasibility, effectiveness, outcomes etc.
Differential: Risk from climate change impacts is not distributed evenly. This generates social and spatial inequalities. Different societal groups perceive risk differently.	This aspect further underlines the importance of different types of adaptation measures in varying extents and scales. This also means that capacities to respond and adapt differ widely across different societal actor groups, hence resulting in different adaptation needs and priorities between actor groups and across geographies. This further emphasizes the need for an actor lens in adaptation.
Dynamic: Risk and its components are changing over time; they are not static.	This aspect of risk and vulnerability adds a temporal dimension to the nature of adaptation and resulting assessment – adaptation options and their feasibility, desirability and effectiveness may change over time

Source: drawing on the literature reviewed in this section

Table 3

2.1.3 Understanding the adaptation solution space and its evaluation

In view of the above definitions and key aspects of adaptation and risk, adaptation options can be understood as "the array of strategies or measures that are available and appropriate for addressing adaptation" (IPCC, 2022a). Adaptation actions or measures essentially aim to limit or reduce climate risk by primarily addressing exposure and vulnerability to the adverse impacts of climate change (Garschagen et al., 2021). Adaptation options can be categorized in multiple ways, for example, according to the key risks they address, such as food and water, critical infrastructure, health, etc. (O'Neill et al., 2022), by sectors (agriculture, transport, water, etc.), by types (structural, institutional, ecological, behavioural), by mode (protect, advance, retreat, accommodate) or by scale (regions, administration, geographical). The categorization of adaptation options adopted in the context of this study is described within the scope of the conceptual framework (cf. section 2.4.3).

Adaptation measures might also interact with each other – by producing synergies and co-benefits but could also lead to negative impacts. The recent addition of the IPCC AR6 climate risk framing includes "risks from responses themselves", referring to the possibility of responses having adverse effects on other societal objectives, having trade-offs, leading to unexpected impacts or triggering path dependencies (IPCC, 2022b). Another development in adaptation literature introduced the concepts of first- and second-order adaptation in response to the critical view of understanding adaptation in a linear fashion. First-order adaptation measures are defined as "strategies and measures that households, communities, or societies develop to adapt to actual or expected climate change consequences and natural hazard phenomena" (Birkmann, 2011, p.818). In contrast, second-order adaptation measures refer to "processes, strategies, and measures that can and most likely need to be executed by households, communities, and societies to adjust to the direct and indirect consequences of the measures and structures implemented within the scope of first-order measures." (ibid.). This dynamic interaction of adaptation measures makes the evaluation of adaptation options more challenging and complex, as such feedback loops can unfold over different dimensions e.g. spatial, temporal, and sectoral.

An increasingly used concept to understand and assess the portfolio of different adaptation options is the 'solution space' for adaptation (Du et al., 2022; Haasnoot et al., 2020; Sainz de Murieta et al., 2014; Wannewitz & Garschagen, 2021). The 'solution space' is defined as "the space within which opportunities and constraints determine why, how, when, and who adapts to climate risks" (Haasnoot et al., 2020, p.1). The IPCC AR6 report emphasizes the concept of 'solutions' as a synonym for other terms such as options, measures, responses, and actions, due to its implicit indication of effectiveness and advancement towards achieving desired goals (Ara Begum et al., 2022). However, there are also some drawbacks of the term, including a sense of finality, suggesting that a problem is 'solved' and the potential of resorting to a narrow set of measures such as a 'technical solution' (or technical 'fix' in line with the Dominant View mentioned earlier). This study adopts a combined approach wherein the conceptual framework in this study refers to 'adaptation options' that make up the solution space.

Given the socially constructed and contested nature of the solution space, what one actor might perceive as a solution could be viewed as creating or compounding risks for another (ibid.). A major requirement in understanding the adaptation solution space is not only identifying the range of options that make up the solution space but also the governance actors and their interactions (Haasnoot et al., 2020). This characteristic feature of the solution space necessitates focusing on the

‘perceived solution space’ for adaptation by different actors in the conceptual framework adopted in this study (cf. 2.4.3 for more details on the ‘perceived solution space’ and actor types).

Understanding and mapping the adaptation solution space is a crucial requirement for assessing the feasibility and effectiveness of adaptation options (de Coninck et al., 2018; Haasnoot et al., 2020). A key characteristic of the adaptation solution space is that it is flexible and can change in response to both exogenous changes, e.g. geophysical changes in natural systems or political changes in societal systems as well as planned actions, e.g. a specific intervention such as a new funding mechanism for adaptation. Such changes can target both biophysical as well as societal dimensions including political, cultural, and socio-economic dimensions (ibid.). Accelerating adaptation action, investment and implementation can be facilitated by an improved understanding of the enabling and constraining conditions that potentially influence different adaptation options (IPCC, 2018a). Given the diversity of approaches to assessing feasibility (beyond the binary ‘yes’ or ‘no’), the concept of feasibility is seen as a frame to understand the range of potential responses and different conditions that might influence them. The multi-dimensional feasibility assessment applied in the IPCC Special Report on the Impacts of 1.5 °C of Global Warming (from here on referred to as IPCC SR 1.5) and the IPCC AR6 is seen as a methodological advancement in the feasibility assessment of the adaptation options that potentially make up the solution space (Allen et al., 2018; de Coninck et al., 2018; IPCC, 2022b; Singh et al., 2020).

The concept of feasibility is defined as “the degree to which climate goals and response options are considered possible and/or desirable” (Singh et al., 2020). It is important to note that this understanding and resulting assessment integrates the notion of desirability and feasibility. However, studies have shown the importance of separating desirability from feasibility as actors might perceive the feasibility of an option differently from its desirability (Dawson et al., 2016; Lemieux & Scott, 2011). Such a multi-dimensional assessment of adaptation options is an advancement in the evaluation of adaptation options and signals a shift away from two prevailing practices: first, a binary assessment of options that looks at the feasibility of adaptation measures as a dichotomy (feasible or not feasible) and second, it goes beyond traditional cost-benefit criteria to accommodate other factors (Fuldauer et al., 2022; Jafino et al., 2021; Singh et al., 2020). Hence, the study goes beyond previous assessments of feasibility by providing a multi-dimensional, comprehensive, and cross-sectoral assessment of different adaptation options across ‘big literature’ (ibid.). In light of the challenges described earlier, few studies have conducted feasibility assessments of adaptation options (cf. 1.2).

The assessment framework considers six dimensions according to which the feasibility of different adaptation measures is evaluated. The six dimensions include environmental, economic, technological, institutional, social, and geophysical. The dimensions are assessed using a barriers framing, i.e. in how far the dimensions have a constraining role on the adaptation measures. A barrier to adaptation is understood as “an impediment to specified adaptation for specified actors in their given context that arises from a condition or a set of conditions” (Eisenack et al., 2014, p.868). It is important to recognize the limits and barriers to adaptation (Eriksen et al. 2011). Building on these dimensions, the conceptual framework and multi-dimensional evaluation of perceived adaptation solution spaces in the context of this study is described in section 2.4.3.

Despite the methodological advancements of this assessment framework, some challenges remain, including assessing synergies and trade-offs of different adaptation options, weighted feasibility to identify which options might potentially be more feasible than others, co-benefits or trade-offs with mitigation and other societal objectives, dynamic interactions of options and feasibility dimensions and finally, spatial-temporal trade-offs and synergies. Trade-offs and potentially negative outcomes over space and time can occur and have to be recognized and evaluated against the background of differing values and interests of affected population groups. The characteristic of first and second-order adaptation implies that in many cases proposed adaptation measures can in combination imply contradictions and conflicts (but possibly even synergies). Furthermore, some types of measures may also create lock-in effects and path dependencies – which may lead to lock-in mechanisms of risk reproduction and yield difficult to change in the future. Such conflicts and shortcomings remain insufficiently addressed in the literature and are of crucial importance.

2.1.4 Conceptualizing effective adaptation to understand adaptation objectives and target actors

Closely related to feasibility, is the conceptual framing of the 'effectiveness' of adaptation options (Owen, 2020; Singh et al., 2022). Although this study does not aim to assess the effectiveness, the concept is closely related to adaptation objectives – a key element of assessing social contracts for adaptation. Effectiveness is assessed in terms of the outcome, which refers to the adaptation objective that is intended to be achieved (Donatti et al., 2020). Hence, the next paragraphs provide a brief review of the latest developments in the assessment of effective adaptation relevant to the scope of this study.

Defining effective adaptation is challenging because there is no single metric to signal progress in adaptation, unlike in mitigation which is often measured in terms of emissions reduced or avoided in tonnes (Dilling et al., 2019; Fisher, 2024; Owen, 2020). The nature of adaptation is highly context-specific, making it difficult to develop a universal definition of adaptation effectiveness (Morgan et al., 2019). Similar to feasibility, effective adaptation might vary across both temporal as well as spatial dimensions. In other words, what might be considered effective today might not be effective anymore in the future, potentially narrowing the solution space for adaptation (Dilling et al., 2019). Similarly, effectiveness may change across different spatial scales, making it difficult to arrive at a universal definition of effectiveness across space.

In dealing with these challenges, previous literature has put forward many recommendations for how to define and assess effectiveness. There are contradicting views – on the one hand, a top-down approach to define a generalizable set of metrics is argued for being useful for assessing effectiveness and support prioritization of funding (Stadelmann et al., 2011). On the other hand, it fails to accommodate the context-specific and "bottom-up" indicators that are important in evaluating the effectiveness of adaptation (Leiter et al., 2019). An advancement in this regard has been the "framing" approach put forward by (Singh et al., 2022) based on a frame analysis. The study developed eleven frames to assess effective adaptation: (1) maximizing economic benefits; (2) improved wellbeing; (3) vulnerability reduction or adaptive capacity enhancement; (4) enhanced resilience; (5) sustainable adaptation; (6) avoiding maladaptation; (7) ecosystem-based adaptation; (8) community-based adaptation; (9) adaptive governance; (10) ensuring equity and justice; (11) transformation. An important characteristic of these frames is their categorization into normative frames, i.e. adaptation as 'goals' or endpoints such as "improved well-being" and process-based

frames, i.e. adaptation as a 'means'. This categorization also results from the definition of adaptation, including both an outcome and a process (goal of adaptation to adapt well vs being well-adapted). For a detailed review of the framings and their implications please see (Singh et al., 2022). This framing is used as an entry point to deductively inform the operationalization of 'adaptation objectives' in the conceptual framework for this study (cf. section 2.4).

Another recent advancement in the literature has been the adaptation-maladaptation framework (Reckien et al., 2023). The important step made by this contribution is that it goes beyond asking what is considered effective adaptation (i.e. adaptation for what) but also 'for whom' and for which system. The framework conceptualizes effectiveness along a continuum to allow for evaluating adaptation responses for mixed outcomes, accommodating actor perspectives and context-specific conditions and temporal changes (ibid.). The framework proposes one filter (number of people) and six outcome criteria namely three systemic-level criteria (ecosystems, GHG emissions, systemic change) and three equity-related criteria (low-income groups, women/girls, marginalized ethnic groups). This aspect (adaptation for whom) is reflected in the own conceptual framework as well (cf. section 2.4).

Despite the conceptual challenges and complexities in defining and assessing effectiveness, it is important to understand how adaptation objectives are framed and conceptualized. This is because it has important implications on adaptation priorities for "what is done, for what purpose, by who, for whom, and with what outcome" (Singh et al., 2022, p. 202). These framings and understandings in the specific contexts where adaptation decision-making takes place seriously affect who benefits from an adaptation intervention and who bears the burden.

2.1.5 Roles and responsibilities for adaptation

It has been well established that adaptation actors need to assume clearly defined roles and responsibilities to deliver effective adaptation (Adger et al., 2013b; Biesbroek et al., 2010, p. 201; Fünfgeld, 2010; Garschagen, 2016; Juhola, 2019; Klein et al., 2018; Mees et al., 2015). While it is important to clarify "precisely what adaptation futures are sought" when defining effective adaptation, an equally important question remains – "what constitutes the fair governance of those adaptive transitions" (Pelling et al., 2015). In other words, while actors might agree on a common goal, objective, or vision for adaptation, e.g. the protection of the most vulnerable individuals, the question arises as to who is expected to play which role and is/should be entrusted with which responsibilities in achieving this goal. For instance, should the protection of the most vulnerable be an individual or collective responsibility (Mees et al., 2015, p.1065).

Roles and responsibilities have been used differently in previous studies in the adaptation context – e.g. interchangeably, without a clear definition, or conflated with one another (Juhola, 2019; Mees et al., 2012; Reckien & Petkova, 2019). Mees et al. (2012) for instance, take an instrumental approach to responsibility, seen as 'who does what' yet conflating it with roles by looking at it as "the roles actors can fulfil" (p. 307). In the typologies of responsibility for adaptation put forward by Juhola (2019), roles are seen as the identity of actors, e.g. public authorities, citizens, private and non-governmental organizations. In a recent global assessment of actors and their roles in climate change adaptation, roles have been defined as an "actor's general position or function within a larger social system and in a certain process" (in this case, adaptation) (Petzold et al., 2023, p.1251). The study defines roles along both cycles – the adaptation cycle (UNFCCC Adaptation Committee,

2019) as well as the policy cycle (Mees et al., 2012). Roles for adaptation include awareness raising, assessing, planning, financing of measures, implementing, monitoring, and evaluating (ibid.). Responsibilities refer to specific tasks and duties that are assigned to the roles (ibid.). Despite the different interpretations of the terms, the studies note that there can be mismatches, ambiguities, and overlaps on and between both levels in allocating roles and responsibilities. The definition of roles and responsibilities used in this study is elaborated in section 2.4 under the conceptual framework.

Multi-actor constellations are often characterized by diverging perceptions of who is seen responsible for what. In addition to the conflicting viewpoints, adaptation governance literature has found that ambiguous and unclear distributions of roles and responsibilities are often highlighted as a barrier to adaptation governance (Biesbroek et al., 2010; Fünfgeld, 2010; Juhola, 2019). It, therefore, becomes important to explicitly draw attention to the question of which actors are seen as responsible for developing and implementing different adaptation measures (Birkmann, 2011). Related to the explicit distribution of responsibilities, Mees et al. (2012) raise and discuss the question of "what kind of sharing of responsibilities is feasible and desirable among public and/or private actors for adaptation" (p.306). Moreover, Petzold et al., (2023) draw attention to a related ambiguity between the de facto or empirical perspective on "who is acting how" and a normative understanding of "who should act how" (p.1250).

All of the above considerations and questions become of central importance for understanding transitions across different risk management regimes (Solecki et al., 2017). Key characteristics of each risk management regime include "a set of assumptions and assertions regarding the conceptualization of risk, the rights and responsibilities of the state and other actors, the mode of risk governance, and the underlying issues of equity and fairness." (ibid.). The authors conceptualize four archetypical risk management regimes ranging from collapse, resistance, resilience, and transformation. The main relevance of the debate on the possible transition of risk management regimes to the scope of the conceptual framework developed below is the societal negotiation on competing visions and the distribution of roles and responsibilities that might need to take place in order to facilitate transitions across such risk management regimes. These questions might become all the more urgent when current risk management regimes need to transform, adaptation options might no longer be feasible or desirable and the de facto and de jure (legal) distribution of roles and responsibilities might not work.

2.2 Conceptualizing social contracts for adaptation

The above section shows that it has been well established that adaptation to the impacts of climate change will require collective efforts from different actors of society such as the state, individuals, civil society organizations, and private sector. Adaptation will not be a silver bullet approach but requires societies to design a risk management portfolio by selecting from a diversity of available options. Adaptation takes place in a socially contested space, wherein different actors might have different and potentially conflicting priorities, that could stem from varying adaptation needs, capacities, and boundaries of risk acceptability. This study aims to conceptually advance the understanding of social contracts for adaptation in response to the increasing calls for research on rethinking, redefining and renegotiating social contracts for climate change adaptation (Adger et al., 2013a; Blackburn & Pelling, 2018; Hayward & O'Brien, 2010). Social contracts for adaptation can be

seen as embedded within the larger domain of governance thinking, in which risk and adaptation governance is defined as "all modes and institutions by which a city's individuals, social groups and organizations of the state sector and the private domain negotiate their interests, exercise their influence and distribute as well as act upon their responsibilities to manage and reduce urban risk and to enable adaptation across all scales and actors in a city" (Garschagen, 2015, p. 608-609). A social contracts lens to risk and adaptation governance is seen to provide a sharper analytical lens in understanding questions on how actors might negotiate potentially diverging goals and visions. Furthermore, actors might have entirely different expectations of how to achieve these goals and visions. In other words, a social contracts lens raises the question of who is responsible for what in the challenging task of adapting to the impacts of climate change?

A social contracts lens makes a highly relevant and timely contribution to understanding and addressing key challenges and concerns at the center of adaptation debates. The relevance of a social contracts lens stems from its particular usefulness in terms of (a) drawing attention to the underlying tensions and contestations in societies around the questions of adaptation priorities and expectations on distributions of roles and responsibilities, that are often implicit and tacit in nature, (b) offering a lens to analyze and potentially inform the process of a societal (re)negotiation of diverging viewpoints towards shaping a coherent social contract. Such a lens makes a timely contribution because the pressures of climate change are increasingly raising new questions around societal adaptation goals and visions and drawing attention to shifting roles and responsibilities between actors such as the state, citizens, private sector, and civil society organizations when transitioning to different risk management regimes. For example, is a relocation to less exposed areas to flooding an individual responsibility or a collective one? While the challenges of adaptation to the impacts of climate change are putting pressure on the current social contracts for many societies across the globe, studies also identify crises as opportunities for rethinking, redefining, and renegotiating social contracts to form coherent social contracts for adaptation (Pelling et al., 2022; Pelling & Dill, 2010).

To get at the framework that develops the conceptualization of social contracts for adaptation and guides the empirical analysis of this study, this section first, provides a concise overview of the origins and classical theories of social contracts, focusing on the aspects relevant to its conceptualization here in the context of adaptation. Second, it reviews the use and application of social contracts in adaptation literature and relevant and related thinking on disaster risk management, resilience, and sustainability.

2.2.1 Origin and classical social contract theory

While the origins of the social contract theory can be traced back to the works of ancient Greek philosophers such as Aristotle and Plato, they are most prominently known through the works of the classical contractarian theorists such as Hobbes, Locke, and Rousseau in the 17th-18th century as part of the Enlightenment project. This sub-section will focus on the key principles of classical social contract theory that are relevant for the conceptualization of social contracts for adaptation in the context of this study (cf. Table 4 in section 2.4.2).

While differences exist in their writings, a unifying principle of classical contractarianism is the view of the social contract as an outcome of the necessity to regulate human relationships through

legitimate, collective governance arrangements shaped by the agreement or consent of the people (Weale, 2004). This notion of consent is, however, achieved through slightly different motivations according to the different classical theorists.

Hobbes, in his work Leviathan (Hobbes, 1651) suggested that the state of nature was characterized by strife, anarchy and a "war of all against all" (Morris, 1999). This forms the premise for a central idea of his theory – that people would voluntarily give up their liberties in exchange for their protection and security by a sovereign ruler.

A central feature of Locke's idea of consent that differs from both the other philosophers is the distinction between "legitimacy is not contingent on consent" but rather it is the legitimate government to which people would consent (Taylor, 2015, p. 4). Locke believed that if the legitimacy of the government is lost, people should have the right to overthrow the government through resistance (Lessnoff, 1990). In contrast to Hobbes, Locke viewed the state of nature as ordered and that people would choose to live in society and have the natural right to select their government to protect their liberties and property. Protection of property plays an important role in Locke's theory of the social contract. He writes "the reason why men enter into society, is the preservation of their property;…it can never be supposed to be the will of the society, that the legislative should have a power to destroy that which everyone designs to secure, by entering into society" (Locke, 1690, Sect.222).

Rousseau on the other hand, believed that property was responsible for corruption in society. In his famous work titled The Social Contract (1762) he stated, "man is born free, and everywhere he is in chains"(Cress, 2006, p.141). This is in reference to his view on the state of nature where people are truly free, but it is when they enter society is when the need arises for a social contract between the government and the people. A defining feature of his theory of the social contract is the emphasis on the "general will" of society, i.e. "Each of us places his person and all his power in common under the supreme direction of the general will; and as one we receive each member as an indivisible part of the whole." (ibid., p.148). According to Rousseau, the government should enact the general will and it is this general will or collective expression of interests that forms the basis of society.

In applying the principles of classical social contract theories to adaptation, previous studies note the following concerns:

First, they challenge the notion of a single social contract between the sovereign ruler and the people who are ruled. It is argued that such a conceptualization excludes the role of other actors that play an increasingly important part in risk governance such as the private sector, civil society organizations, families, households, employers, and other communities (Blackburn & Pelling, 2018). The authors argue for a need to rethink governance structures, emphasizing the importance of collective arrangements. In this regard, they highlight the importance of understanding individual expectations around levels of protection from state and non-state actors against the background of the increasing impacts of climate change.

Second, despite different versions of the classical theorists on the notion of consent, this consensual characteristic of classical contractarianism is challenged by Blackburn & Pelling (2018) due to its suggestion of the social contract as a "comfortable exchange of rights and responsibility between ruler and the ruled" (in reference particularly to Rousseau's thinking) (p.3). As opposed to classical contractarian theory that primarily focuses on understanding the shape of the social

contract, Blackburn & Pelling (2018) call for attention to the mechanisms through which it is produced. Instead, the authors argue for greater analytical attention to Locke's justification of citizen resistance when the legitimacy of the state is lost. This aspect is of great relevance in the adaptation context due to the opportunity such moments of resistance might provide to capture the gaps and contestations around the roles and responsibilities enacted (or not) by different actors. In the disaster context, Pelling & Dill (2010) note the window of opportunity that opens up after a disaster might reveal the gaps in prevailing social contracts thereby offering a space for the renegotiation of the social contract but highlighting that it can drive change that can result in both positive and negative outcomes. Hayward & O'Brien (2010) argue that the renegotiation and redefining of social contracts in the face of climate change will not happen autonomously, "inevitably, gracefully or spontaneously" (p.206) and instead "require debate, discussion, struggle or conflict" (ibid.). Hence, Hayward and O'Brien argue that the works of Rousseau hold inspiration for rethinking "alternatives to market-liberal social contracts as solutions to climate change" (ibid., p.210).

While the key principles of classical social contract theory are crucial in informing their conceptualization of social contracts for adaptation, studies have noted challenges in some respects when transferring to the context of adaptation. The next section reviews adaptation and related debates that explicitly use the notion of social contracts.

2.2.2 Application of social contracts in adaptation and related fields

The notion of social contracts has been applied across various fields, ranging from political science and philosophy where it had its origins, to sociology, for example, Sen & Durano (2014), science, for example, Blue & Davidson (2020), business, and economics, for example, Heydemann (2020), international relations (especially conflict studies), for example, Loewe & Zintl (2021), health science, for example, recovery from the Covid-19 pandemic by Pelling et al. (2022), etc. However, in keeping with the context of this study, this sub-section focuses on the application and advancement of social contracts in the realms of climate change adaptation and related fields of disaster risk, resilience, and sustainability.

In the climate change literature, O'Brien et al. (2009) highlight the potential of resilience thinking in shaping a new social contract in view of the challenges of climate change. They argue for the insights offered by resilience debates for shaping social contracts. These include, for example, the need to address the social context in environmental problems, uncertainty, and the importance of multilevel governance, in forming a social contract. In the context of adaptation to climate change, Adger et al. (2013b) argue for "evolving social contracts as a primary mechanism" by means of which adaptation moves forward (p.1). They argued that "making social contracts explicit may smooth pathways to effective and legitimate adaptation" (ibid.). They highlight the importance of perceived responsibilities and the pivotal role of "expectations" in influencing action and response (Adger et al., 2017). Reflecting on social contracts for climate change, Hayward & O'Brien (2010) raise critical questions that inspire the conceptualization of social contracts for adaptation in this research: "what should be secured, for whom and how" (p.211). They argue, that not considering the normative visions "may simply continue to displace and exacerbate environmental problems across time and space, further obscuring the complex, inequitable and evolving relationships that underpin current ecological and social dilemmas" (ibid., p.200).

Blackburn & Pelling (2018) made important advancements in conceptualizing social contracts as an analytical lens for understanding the politics of adaptation – especially in its distinction of the imagined, practiced, and legal-institutional realms of social contracts. They emphasize that a major contribution of a social contract lens to adaptation lies in "highlighting tensions between need, obligation, and entitlement that underlie contestations over "who" is responsible for "what" in risk governance" (p.2). This work has been particularly inspirational for conceptualizing and operationalizing social contracts for adaptation in this study (cf. section 2.4).

In the context of social contracts for urban adaptation, (Eakin et al., 2020) analyze neighourhood level protests as an expression of collective grievances and expectations toward the state. Raising the question of what is needed for effective social contracts, Willis (2020) draws a parallel to the Covid-19 pandemic and argues for an honest debate and better democracy to drive effective action in response to climate change. More recent conceptual development of "risk social contracts" as an analytical lens argues for the need to understand relations of trust and expectations from citizens towards the state in flood risk governance (Ommer et al., 2024). On the contrary, evidence from social contract analysis in China shows how the politics of distrust drive alternative social mechanisms for action such as mobilizing social capital (Lo et al., 2021). Explicating the link between debates on human security and climate change, Zografos (2017) shows the gaps in the state's role between its legally defined roles and what it delivers in practice. Beyond some of the literature indicated above, most studies have engaged with topics on roles and responsibilities for adaptation as well as adaptation goals and visions without explicitly using the term 'social contract' (cf. 2.1).

In the disaster risk reduction context, studies have invoked the social contract to highlight the impact of development projects on social vulnerability and social cohesion (Mitra et al., 2017) and as a mechanism for re-negotiation of the distribution of security or in post-disaster settings (Pelling & Dill, 2010). Previous literature has shown how disasters trigger and expose inequalities prevalent in social contracts. Studies have also used disasters as "analytical windows" to understand how they might expose underlying inequalities prevalent in the social contract (Siddiqi & Canuday, 2018) and how they lead to the shaping of "intimate social contracts" at the boundaries between informal and formal risk governance in post-disaster contexts (Siddiqi & Blackburn, 2022). Studies have also used a social contracts lens to focus on questions on shifting roles and responsibilities between the state and citizens (Fauzi, 2021; Weber et al., 2024) or in the face of uncertainties related to extreme events and climate change scenarios (Christoplos et al., 2017).

2.3 Relevance of social contracts for adaptation in cities and urban areas

2.3.1 Urban adaptation

While the above-introduced conceptual framing of social contracts for adaptation is relevant and has been applied in multiple contexts and scales – ranging from global, regional, national, and local, the need for explicit social contracts for adaptation is most starkly illustrated in cities, proving a valuable and apt unit of analysis. Notably, more than half of the global population now lives in cities. By 2050, two-thirds of the world's population is expected to live in urban areas, with 90% of this growth expected to occur in cities in the Global South (UN DESA, 2019). According to World Bank

estimates, 143 million climate migrants could be expected to move from rural to urban areas by 2050 in view of economic opportunities (World Bank, 2018).

Cities are characterized by some of the highest adaptation pressure that one can find and therefore deserve urgent and increased critical attention (Dodman et al., 2022b). Urban risk trends have often been explained in terms of changes in natural hazard patterns such as extreme weather events occurring in cities such as heat waves, floods, droughts etc. (World Risk Report, 2014). However, urbanization may also shape urban vulnerability and exposure (especially if not planned properly), acting as a driver of risk. For example, land reclamation and increase of built-up areas often takes place at the expense of losing natural ecosystems and could lead to increase in exposure to hazards (e.g. flood risk) but also higher vulnerability through a negative impact on livelihoods. The most rapid growth in urban vulnerability and exposure is seen to occur in places that are not only at high risk but also have limited adaptive capacities – mostly informal, unplanned settlements in low and middle-income countries in Africa and Asia (Dodman et al., 2022b). With India considered to have the largest population globally since 2023 (UN DESA, 2023) and Mumbai being amongst the top ten cities both in terms of population size overall as well as at risk of sea level rise in both current and future rankings, empirical findings of this dissertation from Mumbai are of strong relevance (Hallegatte et al., 2013; Hanson et al., 2011).

This section argues for an urban focus in assessing social contracts for adaptation in terms of the pivotal role of urbanization:

On the one hand, cities are hotspots of disaster risk and on the frontlines of climate change. Not only are they bearers of the impacts of climate change (Dodman et al., 2022b; Garschagen & Romero-Lankao, 2015; Pelling, 2011; Solecki et al., 2017) but urbanization (in particular poorly planned or uncontrolled) may also act as a driver of risk (Garschagen & Romero-Lankao, 2015). Major drivers of urban vulnerability and exposure often emerge from poor urban planning where disaster risk considerations are not taken into account in land use planning, e.g. weak regulations and enforcement of building codes, protection of ecosystems, infrastructure development in hazard-prone areas (often linked to corruption, profit gains, vote bank politics) etc. (UNDRR, 2013). Furthermore, against the background of an increasing trend in population densities in urban areas and lack of adequate safe and affordable housing, about 1 billion urban inhabitants live in informal settlements that are often located in areas highly exposed to environmental risks such as flooding, pollution from contaminated drainage lines, heat stress, etc. (Satterthwaite, 2007; United Nations, 2019a; Wisner et al., 2003). They are often socio-economically marginalized communities that are disadvantaged in terms of livelihood opportunities, and access to basic civic services such as sanitation, solid waste management, and resources, thereby making them the most affected populations at risk in urban areas. Furthermore, demographic and social characteristics such as age, gender, class, race, ethnic backgrounds, religious orientations etc. could have a compounding effect on urban vulnerability of populations. However, urbanization as a process in itself is not inherently a driver of risk and depends crucially upon how it develops (World Risk Report, 2014).

On the other hand, (and often under-emphasized in scientific and policy debates) are the opportunities offered by cities and urbanization processes for risk reduction by being centres of

growth, nodes of political and economic attention and melting pots of socio-cultural diversity. Cities also have high adaptive capacities in principle in terms of high densities of capital, resources, livelihood opportunities, infrastructure, civic services, etc. While the first argument poses the challenges of the intersection of urbanization and climate change, the latter highlights the chances that cities offer for adaptation and sustainable development, often referred to as the "double effect" of urbanization (Garschagen & Romero-Lankao, 2015). With more built-up area, migration to urban areas, investment and construction of infrastructure that is yet to happen in the coming decades, especially in emerging and transition economies in the Global South, urbanization holds potential for better climate-risk informed planning. Cities like Mumbai, Jakarta, Manila, Ho Chi Minh City, Bangkok, etc., which are hotspots of risk, are at the same time the engines of economic growth and frontiers of progress and development in their countries. Also, the potentially positive reduction in vulnerability in the growing middle classes in many urban areas of emerging and transition economies has received less attention(Garschagen & Romero-Lankao, 2015). In many cases, both tendencies are visible wherein cities are often confronted with stark inequalities where some groups, sectors, and areas within the same city might be severely impacted due to their high vulnerability and exposure, and others might see an increase in their adaptive capacities.

The cross-cutting argument is that what happens in cities will play a critical role in determining the success of adaptation and sustainable development. In view of this critical role that cities play in the response to climate change, they have received increased attention in both policy and scientific debates. In policy spheres, this role of cities has been formally acknowledged and endorsed in several international policy instruments and networks – for example, the New Urban Agenda (UN Habitat, 2016), Sustainable Development Goal 11 (Make cities and human settlements inclusive, safe, resilient, and sustainable), C40 Cities, 100 Resilient Cities, Making Cities Resilient 2030 (UN DRR), etc. Cities and urbanization processes have also received increased attention in scientific debates over the past two decades. This has most recently been reflected in the IPCC's decision to create a dedicated special report on climate change and cities, planned to start in 2024.

2.3.2 Why social contracts for urban adaptation?

In view of the above dynamics of urbanization and its relation to climate change, it can be said that cities represent spaces that bring together very heterogeneous social groups – characterized by socio-cultural diversity, competing economic and political priorities, asymmetric power relations, and differential risk perceptions, different levels of risk acceptance and adaptive capacities (Pelling, 2011). Therefore, it is here that different viewpoints on adaptation goals and priorities may often be conflicting. "These gaps and contestations may arise in view of addressing pertinent questions on political feasibility, power dynamics, and trade-offs involved, such as whose priorities get embedded in adaptation pathways, who decides whose futures are protected and how costs are distributed, which spatio-temporal trade-offs will need to be made, etc." (Doshi & Garschagen, 2023a, p.2)

Furthermore, the increasing impacts of climate change and growing pressures of urban development will require societies to transition between different risk management regimes, in many respects calling for fundamental changes in the way societies adapt through e.g. governance structures, value systems, beliefs, planning regulations, etc. These transitions might become necessary for example, when the current risk management regime no longer works, adaptation

options start to approach their limits or are no longer effective. Solecki et al. (2017) emphasize the importance of these transitions as analytical spaces to identify "competing transitional visions and trajectories, e.g. for greater individual or collective responsibilities in risk management" and negotiation of trade-offs. Different adaptation options need to be evaluated in terms of their desirability, feasibility, and effectiveness and should be deliberated openly and inclusively. Coherent social contracts would help to foster the transition to fair, effective, and efficient adaptation. Noting the importance of investigating "imaginaries" in urban transitions (Foley et al., 2020; Jasanoff & Kim, 2015) and the recent call for "disrupting imaginaries and practices" in urban adaptation in a special issue (Broto et al., 2024), the particular focus on imagined social contracts for adaptation in this study is highly relevant to current urban adaptation debates. The special issue especially calls for the disruption of adaptation imaginaries in the Global South, that are often relying on best practices for adaptation in large cities of richer, industrialized nations on "dominant adaptation imaginaries" that are often technocratic in nature (Eriksen et al., 2021).

Therefore, this section makes the argument for the relevance of focusing this study on the assessment of social contracts for urban adaptation. Cities, in particular, in transition economies in the Global South that are at the epicenter of dynamic shifts in terms of both urbanization and impacts of climate change illustrate most starkly the need for coherent social contracts and hence, deserve immediate attention. Finally, in their pivotal roles as hotspots of risk but also importantly, as beacons of innovation and engines of economic growth, they offer significant potential for risk reduction.

2.4 Own conceptual framework for assessing social contracts for adaptation

Building on the conceptual debates in the literature reviewed above, this section presents the conceptual framework developed to guide this study's assessment of social contracts for adaptation and advance the current conceptual debates. As a first step, the study defines social contracts for adaptation in response to the lack of a definition noted earlier. Secondly, this is followed by the conceptual framework, including its key characteristics and elements that guide the empirical research undertaken in this study (Figure 3). Finally, this section concludes with the conceptual framework guiding the multi-dimensional evaluation of perceived adaptation solution spaces (Figure 4) – which provides essential insights on the way to understanding and assessing social contracts for adaptation.

2.4.1 Defining social contracts for adaptation

First and foremost, it is important to define social contracts for adaptation, in response to this gap in the conceptual literature mentioned above. A social contract for adaptation is defined as a *"collective arrangement between different actors of a society on the overall vision and goals as well as the mutual distribution of roles and responsibilities to achieve those goals"* (Doshi & Garschagen, 2023a, p.1). In other words, a social contract describes the collective arrangement of what a society wants and how it gets there. Inspired by, for instance, Hayward & O'Brien (2010) and Blackburn & Pelling (2018) (cf. 2.2.2), the definition advances the conceptual framing of social contracts for adaptation by explicitly integrating the consideration of adaptation goals and normative visions that are often embedded in social contracts – in contrast to most social contract framings in adaptation literature that only consider adaptation goals and visions implicitly and largely focus explicitly on

roles and responsibilities. The 'collective' nature of the social contract and the 'mutual' distribution of roles and responsibilities emphasizes the importance of inclusion and equity, while being aware that such an arrangement would require trade-offs that will have to be made between different adaptation goals and visions, for example between reducing vulnerability, increasing equity, and improving the resilience of the system as a whole (Adger et al., 2017) as well as lead to negotiations around questions of roles and responsibilities.

2.4.2 Conceptual framework on social contracts for adaptation – key characteristics and elements

This sub-section introduces the key characteristics and elements of the conceptual framework on social contracts for adaptation that guide this study (Figure 3). Table 4 summarizes selected characteristics of classical contractarianism and their relevance for defining and assessing social contracts for adaptation in this study.

Table 4 | Selected characteristics of social contract theory and their relevance for adaptation debates

Characteristic of social contract theory	Relevance for adaptation and application in this study
Notion of consent	Invites critical reflection on the need for collective societal agreement in the formation of a social contract for adaptation that is often taking place in a socially contested space; inspires a nuanced distinction between different levels of agreement for the formation of a coherent social contract for adaptation (Type 1 and Type 2)
Mutual exchange of rights and responsibilities	Provides analytical guidance to better understand the distribution of roles and responsibilities for adaptation between different actors of society
General will	Brings attention to the need for understanding the shared societal goals and visions; encourages a broader vision of whose voices are included in the deliberation of social contracts across spatial and temporal spaces; directs the actor-specific lens adopted in this study by drawing attention to the importance of perceived adaptation solution spaces and their evaluation, perceived goals and visions as well as perceived distributions of roles and responsibilities
State-society relations	Directs attention for the need to broaden the scope of actors that can potentially be involved in social contracts for adaptation to recognize the role of non-state actors such as NGOs and civil society organizations, international agencies, local neighbourhood collectives etc. as important governance players in adaptation.
Reciprocal nature and definition of state legitimacy	Draws attention to the need for understanding the social contracts held not only observable in reality or laid out in formally codified documents but also to the 'imagined' or normative expectations of actors
Loss of state legitimacy	Guides the identification and assessment of gaps and contestations and provides analytical guidance on capturing them in moments and spaces when such gaps might manifest themselves, e.g. post-disaster, resistance movements, protests etc. but also acknowledge the existence of tacit, hidden, implicit expressions that might be harder to capture (i.e. the imagined social contracts)
Redefining the social contract	Highlights the need for the (re)negotiation of social contracts for adaptation to be undertaken actively and not expect / wait for it to happen autonomously; underlines the importance of making explicit the embedded visions for adaptation and expected roles and responsibilities to trigger a discussion and negotiation of a social contract

Source: own draft, drawing on literature discussed here

Table 4

Two overarching important characteristics guiding the conceptual framework are presented below:

(1) This research acknowledges the proposition of classical contract theory of the social contract as an outcome of consent (Cress, 2006; Rousseau, 1762). However, it suggests a tweak in this thinking of consent when applying it to social contracts for adaptation since adaptation often occurs in a socially contested space. In this framework, social contracts are conceptualized to be of two types (Figure 2). A Type 1 social contract describes an arrangement "where actors' visions and perceptions on mutual roles and responsibilities do not align but where actors seek a social contract to precisely mediate these differences" (Doshi & Garschagen, 2023a, p.1). A Type 2 social contract refers to an arrangement where

"actors' visions and perceptions on mutual roles and responsibilities align and actors seek a social contract to explicate and formalize this agreement." (ibid.).

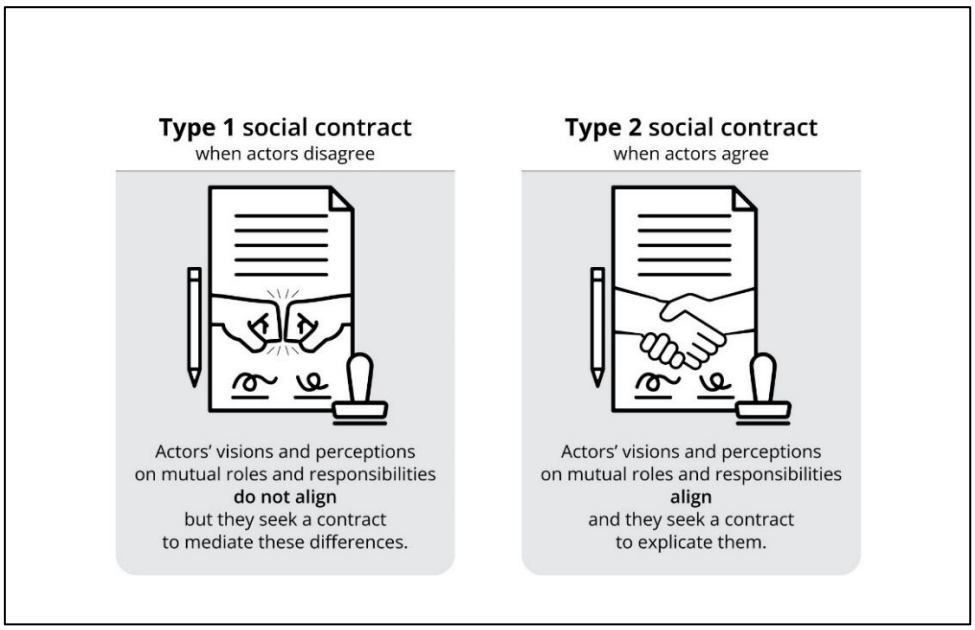


Figure 2: Types of social contracts based on the level of agreement, source: own draft, building in part on (Garschagen et al., forthcoming) (with graphical support from Andrés Alegria)

(2) An important feature of social contracts is that they may be explicit but are often implicit or tacit in nature (Hayward & O'Brien, 2010). In agreement with Blackburn & Pelling (2018)'s conceptual distinction of social contracts into three realms (imagined, practiced, and legal-institutional), the framework developed here suggests that within a Type 1 and Type 2 social contract, there can be three realms —imagined (ISC), practiced (PSC) and legal-institutional (LSC) (Table 5). This three-fold distinction embedded into Type 1 and Type 2 social contracts contributes valuable insights into the tensions and gaps as well as synergies and overlaps between goals and visions as well as roles and responsibilities held de jure or de facto. The 'practiced' realms "describes the 'real-life' goals and observable (de facto) distribution of roles and responsibilities for adaptation between actors" (Doshi & Garschagen, 2023a, p.1). The 'legal-institutional' "describes the formally defined goals and visions and legally encoded (de jure) distribution of roles and responsibilities for adaptation between actors" (ibid.). The 'imagined' realm "describes actors' envisioned goals and viewpoints on the distribution of roles and responsibilities" (ibid.). Moreover, the 'imagined' dimension draws attention to the normative visions and perceptions of what actors believe should or want to be pursued. It is important to highlight that the highly implicit and tacit nature of the 'imagined' social contracts make them difficult to capture yet play a crucial role in shaping the other two dimensions. The main characteristics, definitions, and their application in the context of this research are detailed in Table 5.

Table 5 | Main characteristics relevant for the analytical application of the three forms of social contracts – Imagined, Practiced and Legal-institutional social contract

	Imagined Social Contracts (ISC)	Practiced Social Contracts (PSC)	Legal-institutional Social Contracts (LSC)
Rationale for why we need to talk about these	Provides the opportunity to lay open the heterogeneous/diverse/ diverging viewpoints which are often implicit, tacit, and difficult to capture	Allows an understanding of the existing distribution of roles and responsibilities (de facto)	Helps to identify the legally defined roles and responsibilities held by different actors (de jure)
Definition	Describes actors' envisioned goals and viewpoints on the distribution of roles and responsibilities	Describes the "real-life" goals and observable distribution of roles and responsibilities between actors	Describes the formally defined goals and visions and legally encoded distribution of roles and responsibilities between actors
Core question in this analysis	Which adaptation goals and visions are imagined and desired? Which roles and responsibilities are imagined and expected?	Which adaptation goals and visions are pursued in reality? Which roles and responsibilities are observed and performed?	Which adaptation goals and visions are legally and institutionally defined? Which roles and responsibilities are formally codified?
Forms of expression	Perception ("this is what I believe it to be"/ what they think the actor will do); expectation ("this is how it should be"/ what the actor should do); hope/aspiration ("this is how I wish it to be"/what they hope or think the actor can be doing)	Observable in "real-life" and performed in everyday settings	Defined through formally codified in legal-institutional and constitutional frameworks
Existing space	Implicit/ tacit/imagined space	Material space	Formal codified space

Source: own draft (Doshi & Garschagen, 2023a), based strongly on Blackburn and Pelling (2018)

Table 5

The center stage for the empirical analysis of this study is on understanding the imagined social contracts (Table 6) and their relations to the practiced and legal social contracts. The emphasis on the 'imagined' realm opens up the analytical space for understanding actors' expectations, normative visions, and desired objectives. The imagined social contracts might not only emerge as a consequence of the practiced and legal dimensions but also influence them. The imagined realms highlight the central importance of expectations from and towards different actors in social contracts and how they influence the "practiced" dimension, i.e., how individuals respond and act in reality as well as in shaping the legal and institutional dimension. Disasters and crises are often when these expectations (and gaps between them) become most apparent (Adger et al., 2017; Willis, 2020). Hence, this study argues that on the way toward shaping the legal-institutional and practiced realms of social contracts, "the most immediate need is a better understanding of the potentially

diverging ways in which different actors envision new roles and responsibilities for other actors and themselves, i.e. which ISCs they have and wish for" (Doshi & Garschagen, 2023a, p.2).

Table 6 | Selected aspects of Imagined Social Contracts (ISCs) and their relevance for adaptation

Relevance to adaptation in general	Helps to identify gaps and contestations in subjective viewpoints of adaptation goals and the negotiations of the roadmap to achieve them – especially those which do not get reflected in "practice" (PSC) or "policy" (LSC) Opens the debate on socio-cultural limits to adaptation and boundaries of risk tolerance and acceptability Analytical space to make explicit the discussion and negotiation of trade-offs – that there will be winners and losers in adaptation.
Relevance to this study & **Relation to social listening**	ISCs help to capture diverging viewpoints in the debate and potential gaps and contestations between different actors or within the same actor group ISCs constitute the core analytical space to capture the envisioned goals and roles and responsibilities for flood risk management Qualitative analysis of sentiments allows to reveal that there might be gaps and contestations in the first place ISCs are changing and social listening allows to capture those changes at a rapid speed because of the speed of data collection and possibility to do long term research. Social listening provides an unsolicited approach to capturing 'unbiased' ISCs "Digital divide" and ISCs – whose voices get heard – how does social media shape ISCs?
Relation to evaluation of solution spaces for adaptation	It is important to understand the solution space that constitutes the normative visions and goals for adaptation. Furthermore, it is not just sufficient to understand which options make up the solution space but also how different actors evaluate their perceived solution spaces for criteria of feasibility and desirability.
Relation to PSC	Gaps between ISCs and PSC shows whose priorities and values are embedded in the real world, in other words highlighting power relations Whereas closeness to PSC may indicate capacity for citizen-led action to leverage priorities for adaptation
Relation to LSC	Closeness between ISCs and LSC may also help to trace where the calls for legally codified roles and responsibilities came from. Gaps between LSC and ISCs may indicate complacent citizenship (for eg. due to political apathy).
Relation to PSC/LSC	It may or may not be reflected in PSC or LSC. Provide space to analyse the negotiation of moral claims and obligations which may also play an important role in influencing LSC and PSC. PSC is seen as "the product of negotiation between multiple conflicting ISCs (which may coexist) and the LSC, and may sit closer to one, both or neither"

Source: own draft (Doshi & Garschagen, 2023a), based strongly on Blackburn and Pelling (2018)

Table 6

The explicit focus on the three realms in the conceptual framework guiding this analysis allows for a more detailed assessment of the potential gaps and contestations within and between the three realms of social contracts (Figure 3), e.g. rifts between the de facto, observable distribution of roles

and responsibilities (practiced) and the de jure stipulations on formally defined roles and responsibilities (legal). Gaps could also exist within one realm, e.g., when different actors have different imagined social contracts in mind regarding different adaptation goals and the distribution of roles and responsibilities to achieve them. However, for social contracts to be effective, all three realms need to be aligned – with corresponding legal-institutional and regulatory environments, public debates to understand adaptation needs, demands and priorities and finally, observable action on the agreed social contracts. While it is acknowledged that it might not be possible to entirely overcome these gaps and resolve the divergences, the framework suggests that at least laying open these differences and becoming aware of them is a first necessary step. This would allow actors to potentially engage in a debate or negotiation to form a Type 1 social contract, where such differences could be discussed to find a way to manage these contestations (even if they continue to exist). Finding a way to manage these gaps, could potentially guide the negotiations towards resolving them and forming a Type 2 social contract.

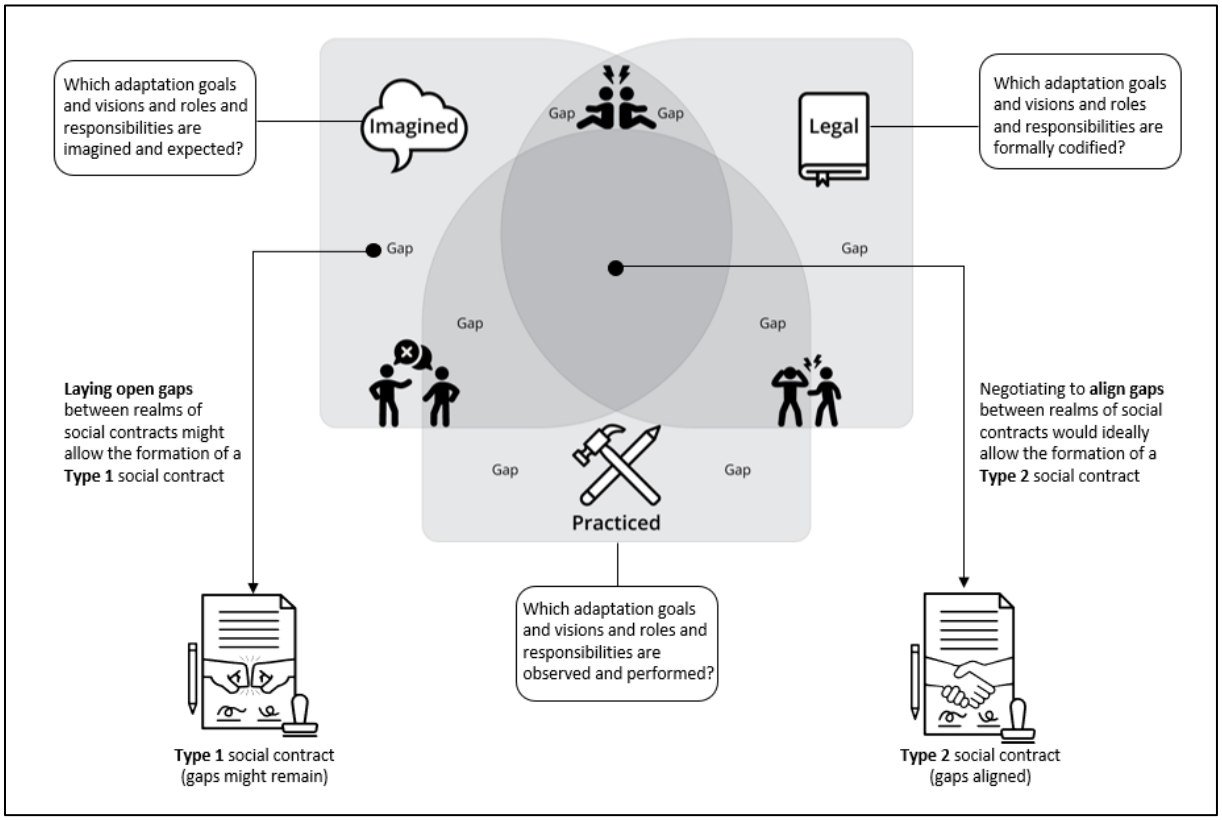


Figure 3: Conceptual framework showing the types, realms, and gaps in social contracts, source: own draft, building in part on (Garschagen et al., forthcoming)(with graphical support from Andrés Alegria)

Furthermore, given the nature of the deep injustices embedded in many social contracts and the complexity of climate change, the conceptual framework suggests that redefining the social contract is not a process that will occur inevitably or 'autonomously' (Hayward & O'Brien, 2010). Instead, this will require a "radical questioning of responses" and "debate, discussion, struggle or conflict" (Hayward & O'Brien, 2010, p. 206). To inform that process, the conceptual framework developed here suggests that a major step is to lay open and make explicit the often tacit and implicit viewpoints different actors have on adaptation goals and visions (for themselves as well as others) as well as expectations on the distribution of roles and responsibilities (for themselves and

others) regarding climate change adaptation in all three realms but especially in the 'imagined' realm. Second, it is important to understand why these gaps and contestations might exist in the first place. Third, examine if and how actors deal with potentially diverging viewpoints and negotiate these differences. Fourth, assess whether and how they arrive at a collective arrangement that allows to mediate the gaps in their viewpoints. Finally, analyze if and how actors ideally manage to agree on shared goals and visions for adaptation as well as how the roles and responsibilities to achieve them should be distributed.

Having outlined the key characteristics that guide the development of the own conceptual framework, the next paragraphs turn to the key elements or building blocks of the social contracts that guide the operationalization and empirical analysis in this study. These include the following four elements: desired adaptation objectives, target/beneficiary actors/systems, roles and responsibilities for adaptation, and actors ascribed with roles and responsibilities.

Adaptation objectives: A key contribution of the conceptual framework is the explicit focus on adaptation objectives, or in other words "adaptation for what", a question that has been largely considered implicitly in conceptual debates on social contracts. The value of separating and specifically assessing actors' desired adaptation objectives in social contracts debates that have thus far focused on the distribution of roles and responsibilities or "who does/should do what" to "how do we get there" (if actors agree or find an arrangement to deal with potentially conflicting objectives). In the absence of a concrete definition of adaptation objectives in the literature, this study defines adaptation objectives to reflect the normative understanding of what actors want to achieve through adaptation or in the process of adapting (acknowledging the different goals of adaptation – "to be well-adapted" vs "to adapt well")(Downing, T. (unpublished manuscript) cited in Tschakert & Dietrich, 2010, p.2). The focus here is on qualitatively capturing and assessing the general goal or direction towards which adaptation is headed.

Actors' desired adaptation objectives are seen as indicating the direction toward a goal but are noted by Goonesekera & Olazabal (2022) as still ambiguous for operationalizing elements to assess (especially in a quantitative sense). However, since the study does not aim to quantitatively assess adaptation objectives, this is not necessarily an issue for the study presented here. Adaptation objectives could further enrich the conceptual debate and assessments of effectiveness because depending on which objective is pursued, influences how the effectiveness of adaptation options is evaluated and interpreted (Singh et al., 2022). The eleven frames of assessing effectiveness by (Singh et al., 2022) deductively inform the empirical assessment. In combination with inductive insights from the data, the study arrives at seven key objectives (cf. 5.3). Stemming from the framing of effectiveness (cf. 2.1.4) objectives can be both process-based, e.g. fairness through an emphasis on procedural justice, or output-based, e.g. efficiency in terms of minimizing costs.

Target actors or systems: Closely related to assessing actors' desired adaptation objectives is the question 'for whom' the objectives are, in other words, who is intended to benefit from adaptation. This question 'for whom' has been addressed in the recently published adaptation-maladaptation framework, referred to earlier (Reckien et al., 2023). However, the contribution of this framework lies in the intersection of the question "for what" with "for whom", through the lens of different actors. This element is operationalized as "target/beneficiary actors/systems" who are

intended to benefit from the identified adaptation response. This element has been developed in the conceptual framework to accommodate beneficiaries that can be both actors as well as systems (e.g. natural ecosystems). This element could refer to different actors such as state, citizens, private sector, or academia and systems such as the natural ecosystem. Here, by "whom" the study refers to actor groups for whom the objectives are intended to benefit rather than counting individual beneficiaries. To prevent taxonomical confusion with the question "adaptation for what" that refers to adaptation objectives in this study, "adaptation for whom" is seen here to refer to both actors as well as systems that are envisioned as beneficiaries of adaptation options. The integration of this element helps to sharpen the analytical lens on understanding which actors or systems are intended to benefit through different adaptation measures. It has been well established that climate change impacts different actors and systems differently (due to differing exposure and vulnerability) and that diverse actors and systems have different capacities to adapt to the impacts of climate change (Araos et al., 2021).

Roles and responsibilities: A key pillar – and mostly emphasized element in the conceptual debates on social contracts are roles and responsibilities. In view of the fuzziness and interchangeable use of the terms 'roles' and 'responsibilities' (cf. 2.1.5), the study adopts the definition of roles and responsibilities as put forward by (Petzold et al., 2023). Roles are defined as " an actor's general position or function within a larger social system and in a certain process, here, climate change adaptation." (Petzold et al., 2023, p.1251). Responsibilities are defined as the "specific tasks and duties that come with roles" (ibid.). The categories are deductively applied in the coding and analysis, while at the same time being inductively informed by the empirical data.

Ascribed actors: The framework links the types of roles and responsibilities for adaptation (above) to the ascribed actor, i.e. the actor or actor constellations that are assigned to perform the respective roles and responsibilities. Following the actor lens used in this study, the analysis focuses on perceived roles and responsibilities. Different actor groups may have diverging perceptions of who is responsible for what in adaptation. Actors may ascribe roles and responsibilities to various actors, ranging from the state, private sector, civil society, citizens and academia, constellations thereof, or even to themselves (self-responsibility). The specific actor or actor groups may vary across different adaptation options, spatial scales, over time, etc., and be influenced by contextual factors such as institutional arrangements of the place, risk perception of the ascribing actor, own capacities, etc. Given the political and financial implications of adaptation, actors may often remain ambiguous on the mutual allocation of roles and responsibilities for adaptation to different actors. Unclear distributions of roles and responsibilities have been identified as a major barrier in adaptation governance yet remain insufficiently addressed in the literature. Therefore, this study argues for the need to make explicit and understand actors' expectations of roles and responsibilities for adaptation from different actors or themselves.

Hence, the above sub-section introduced the conceptual framework that was developed to guide this study for understanding and assessing social contracts, including its key characteristics and elements.

2.4.3 Conceptual framework on 'perceived solution spaces' for adaptation

The study argues that a major step on the way toward informing the process of shaping coherent social contracts for adaptation is to understand how different actors perceive and evaluate solution

spaces for adaptation. This sub-section turns to the conceptual framing developed here for the evaluation of 'perceived' adaptation solution spaces, which integrates an actor-specific lens and builds on the existing concept of solution spaces for adaptation (Haasnoot et al., 2020). To identify actors' adaptation goals and visions and expectations regarding the distribution of roles and responsibilities for adaptation, it is important to first understand which adaptation options they desire (or not) and how they evaluate the feasibility of these options. The following sub-section introduces the key elements of the conceptual framework guiding the assessment of the multi-dimensional evaluation of perceived adaptation solution spaces in this study (Figure 4).

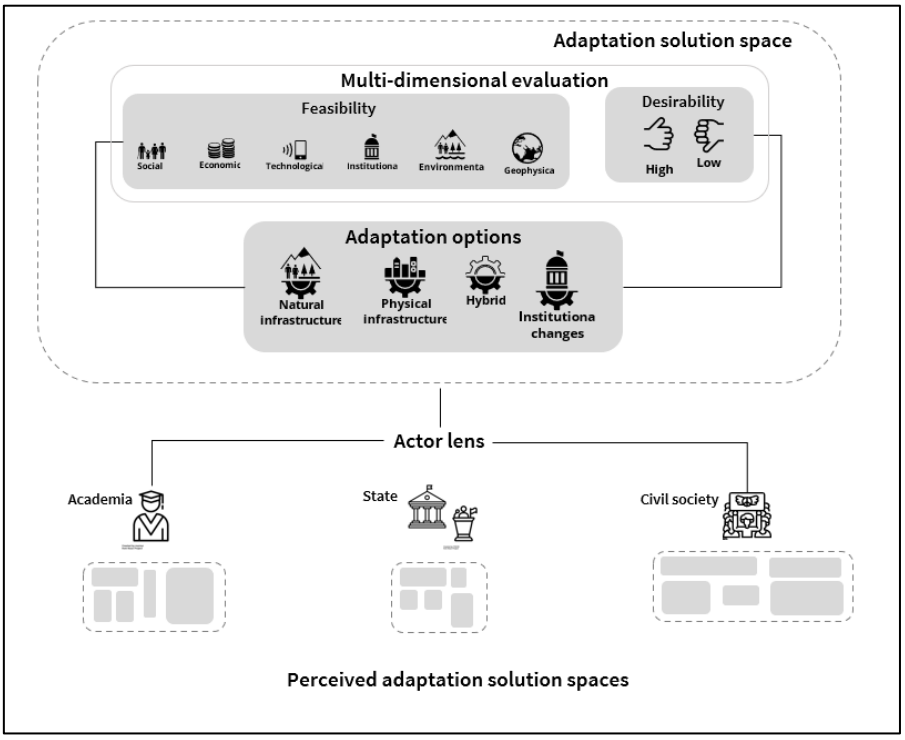


Figure 4: Key conceptual elements of the multi-dimensional evaluation of perceived adaptation solution spaces, source: own draft, building in part on (Garschagen et al., forthcoming)(with graphical support from Andrés Alegria)

Actor-oriented perceived solution space: Given the "socially constructed" nature of the adaptation solution space which is often "contested by actors with different norms, values, and interests", this study focuses on "perceived adaptation solution spaces" (Haasnoot et al., 2020). As adaptation is context-specific, the perspectives of different actor groups regarding their perceived needs and capacities as well as their actor-specific views on the pros and cons of different measures are important to consider. Actors, in the context of this study refer to actor types, including state and non-state actors such as individuals, civil society, and academia. Negotiating these views and designing portfolios of adaption measures includes difficult choices in setting priorities and navigating trade-offs – all of which might change over time. Hence, an actor lens allows to capture how different actors view and evaluate their adaptation solution space. It is important to note that while the study primarily aims to capture inter-actor group differences, it does not comprehensively assess intra-actor group differences in viewpoints yet acknowledges the diversity of values and priorities that might exist within actor groups. In the scope of this framework, the perceived adaptation solution space is defined as "the space comprising adaptation options as identified and

perceived by actors in a given setting" (Doshi & Garschagen, 2023b, p.3), in this case, the flood risk management in Mumbai.

Adaptation options: The categorization of the adaptation options in the framework is inspired by the IPCC's grouping (physical, natural, and social infrastructures) (Dodman et al., 2022b). However, informed by the interview data, the categories that are adjusted and developed for the adaptation options within the framework are as follows: grey/physical infrastructure, green/ natural infrastructure, institutional changes, and hybrid. In the absence of definitions of these categories, own definitions are put forward. Grey/physical infrastructure options refer to the physical or built structures, often associated with hard, engineering solutions, designed to address climate-related risks (e.g. dykes, sea walls, dams, etc.). Green/natural infrastructure options refer to measures using natural and nature-based solutions that aim to benefit ecosystems and natural processes (e.g. mangrove forestation, protection of wetlands, urban tree cover, etc.). Institutional changes refer to strategies or measures that involve changes in policies, practices and organizational structures to address the risks of climate change (e.g. governance reforms, laws and regulations, etc.). Hybrid options refer to strategies or measures that combine two of the previous types of options, resulting in combinations such as "green-grey", "grey-institutional" or "green-institutional" (e.g. integrated coastal zone management, climate-smart agriculture, etc.).

Multi-dimensional evaluation in terms of desirability and feasibility: The boundaries of the perceived adaptation solution space are therefore outlined by the adaptation options identified by the actors and their evaluation in terms of desirability and feasibility. In doing so, it seems important to go beyond current feasibility assessment approaches not only in terms of actor-specific perspectives but also in terms of separating the assessment of the perceived desirability of options from the perceived feasibility. While these two aspects are often integrated together in current approaches (notably through the integration of notions of social acceptance into the assessment of feasibility) (Singh et al., 2020), it is becoming increasingly clear that actors often perceive and evaluate options differently with regard to desirability and feasibility and that an explicit focus on both is necessary for scientific assessments of adaptation. Hence, the conceptual framework here advances current approaches by explicitly allowing to assess how actors might assess both the feasibility of adaptation options, i.e. "what is possible" as well as the desirability or "what is wanted".

This study adopts the six dimensions of the IPCC's feasibility assessment mentioned above. The current feasibility assessment employs a 'barriers' approach and assesses the different dimensions with regard to their potentially constraining role for the identified adaptation measures. However, following the defining characteristic of adaptation which says that adaptation can also be undertaken to exploit opportunities, it should be important to assess also the enabling role of the different feasibility dimensions. Hence, the framework goes beyond current approaches in feasibility assessments by dividing each dimension into positive and negative aspects to assess how actors emphasize the role of the dimension. In other words, it asks not only how a dimension could act as a constraint but also how it may enable the specific adaptation option. Under a positive framing, it is assessed if an actor emphasizes the dimension as an enabling factor. A negative framing indicates that the actor emphasizes the dimension to play a constraining role in the feasibility of the adaptation option (Adger et al., 2007; Biesbroek et al., 2015; Ford et al., 2017).

3. METHODOLOGY

This chapter outlines the methodological approach adopted in this study. The chapter begins with a discussion of the paradigmatic reflections guiding this research, including the ontological and epistemological assumptions of the study (3.1). In the second section, my positionality as a researcher is considered, highlighting the potential influence of my background on the research (3.2). Following this, the third section presents the research design, including the specific steps undertaken (3.3). Finally, the fourth section turns to the individual methods adopted in this study, including the data collection and analysis approach adopted (3.4). These sections lay the basis for understanding the methodological approach and provide context for interpreting the results presented and discussed later in the study (Chapters 5 and 6).

3.1 Paradigmatic reflections

Paradigmatic reflection is a crucial part of every research as it defines what the researcher recognizes as reality and knowledge (ontology) and how and how much of this reality and knowledge can be known (epistemology). In other words, ontology is concerned with "what exists for people to know about" and epistemology is concerned with "how people create knowledge and what is possible to know" (Moon & Blackman, 2014, p.1170). Hence, taken together, the ontological and epistemological assumptions of a research project are paramount in the design of the research methodology, its analysis, interpretation, and limitations. They also underlie the very object of research in terms of what is examined, why, and to what extent. Hence, it is important to reflect on the ontological and epistemological positions of this research and how they guided the methodology adopted. Taken together, reflections on these three questions – ontology, epistemology, and methodology show which paradigms informed the research.

This research is rooted in the social science discipline. It adopts a human geography lens to study climate risk and adaptation. Against the background and research objectives of this study (cf. Chapter 1), I adopted the ontological understanding of critical realism which recognizes an independent reality (also referred to as the intransitive objects of knowledge (Bhaskar, 1975, p.21), that is distinct from the "transitive objects of knowledge" (ibid.) or, in other words, our knowledge of this reality. It is critical because it is not entirely apprehensible by the researcher and cannot be uncovered in a positivist manner. Instead, critical realism argues that reality is filtered through judgmental rationality and relativist knowledge. Additionally, I find the constructivist line of argumentation instrumental in which actors continually accomplish the social meanings and interpretation of reality. It implies that social interpretation and meanings of phenomena are not only produced through social interaction but that they are also in a constant state of revision.

Combining these two perspectives on reality helped me to understand the concept of social contracts and their dimensions – imagined, practiced, and legal-institutional, as dependent on the perceived understanding and knowledge of different actors. Moreover, this ontological realism together with constructivist perspectives, allowed me to approach social contracts for adaptation as intangible realities that are negotiated and represent an outcome of societal agreement between different social actors on a shared understanding of adaptation goals and visions, and roles and responsibilities. Hence, social contracts are not seen as static or pre-existing but are continually seen as being shaped by societal actors' views, expectations, demands, priorities, and capacities. Furthermore, a relativist understanding of reality helped me recognize and capture different actors'

views on their desired objectives and perceptions on the distribution of roles and responsibilities for adaptation. Hence, the ontological independence of reality suggests that it is not entirely apprehensible.

This standpoint is very different from the ontological assumption in natural sciences, in which reality pre-exists and waits to be discovered in a positivist manner. For example, the ontological understanding of the "dominant view" (cf. 2.1.1) assumes a causal relationship between hazards and their impact on social systems that result in a disaster, thereby equating risk with hazard. Hewitt (1983) instead critiqued the dominant view and called for a reconsideration of its ontological view by arguing that a disaster is the result of a culmination of a human community that is exposed and vulnerable. Hence, risk is at least in part, a product of social factors – depending on exposure (which is not only from the physical position of the individual within reach of the hazard but also linked to structural factors (such as historical, social, cultural etc.) and agency (decision-making by the individual) and vulnerability, including why the individual is vulnerable.

The ontological position in this study does not see social phenomena entirely as "external facts that are beyond our reach or influence" (Bryman, 2012, p.32) and only need to be uncovered in a purely objectivist manner. However, I believe that natural processes such as hazards and physical exposure are real, and critical realist understandings need to complement the assessment of such research objects. Hence, while constructivist elements are important in guiding this research, I do not adopt a radically constructivist approach. Instead, I argue for complementing with critical realist perspectives.

Following this ontological understanding of reality, critical realism argues for transitive and intransitive dimensions of science (Bhaskar, 1998). In other words, "our knowledge is transitive, what our knowledge is *of* is intransitive" (Yucel, 2018, p.412). Therefore, I adopt the epistemological stance of subjectivity in critical realism, which follows the argument that each person may have a different understanding of reality. Bhaskar (1975, p.39), thereby critiques an "epistemic fallacy" or conflating the ontological with the epistemological, as in positivism and constructivism (Bhaskar, 1998, p.27). Instead of an extreme epistemic relativism, I adopt the epistemological stance of fallibilism, according to which knowledge may be socially constructed and fallible (Yucel, 2018). In addition, constructivist ideas helped me explore in detail the particular research focus of this study - how different actors perceive and construct social contracts for adaptation in a specific context.

Adopting the above ontological and epistemological assumptions of critical realism with elements of social constructivism, helped me to understand social contracts, its elements including goals and visions, roles and responsibilities, and the gaps between the different dimensions of social contracts, as dependent on the subjective perceptions of different actors. Given that there is an independent reality that cannot be fully grasped, social contracts can never be fully objectively assessed. However, constructivist ideas helped me to better understand how actors perceive and construct their "imagined social contracts" for adaptation and which gaps they potentially create. For example, through social listening, I could observe how different actors interact, create, and negotiate their subjective meanings on the distribution of roles and responsibilities for flood risk management. Following constructivist ideas, I adopted semi-structured interviews, where questions were kept broad so that actors could construct their meanings of the situation as far as possible.

3.2 Positionality

Following this epistemological stance of the subjective understanding of knowledge, it becomes my responsibility as a researcher to acknowledge my positionality and influence on this research across different stages. This ranged from the development of the research question to the analysis and interpretation of the results. Being female, seemingly young, Indian, born and raised in an urban middle-class family in India with academic training in both India and over almost nine years in Germany, I hereby reflect on the potential biases and challenges that these characteristics and experiences might bring to the research in terms of data collection and analysis, as well as how I tried to address them. I see myself as neither a complete insider nor a complete outsider; instead, I see both perspectives on a continuum along which I move back and forth, depending on the context, time, location, and participants. I was able to combine my insider perspectives, coming from the Global South, yet having an element of an outsider perspective due to my long stay and the Western influence of academic development in the Global North.

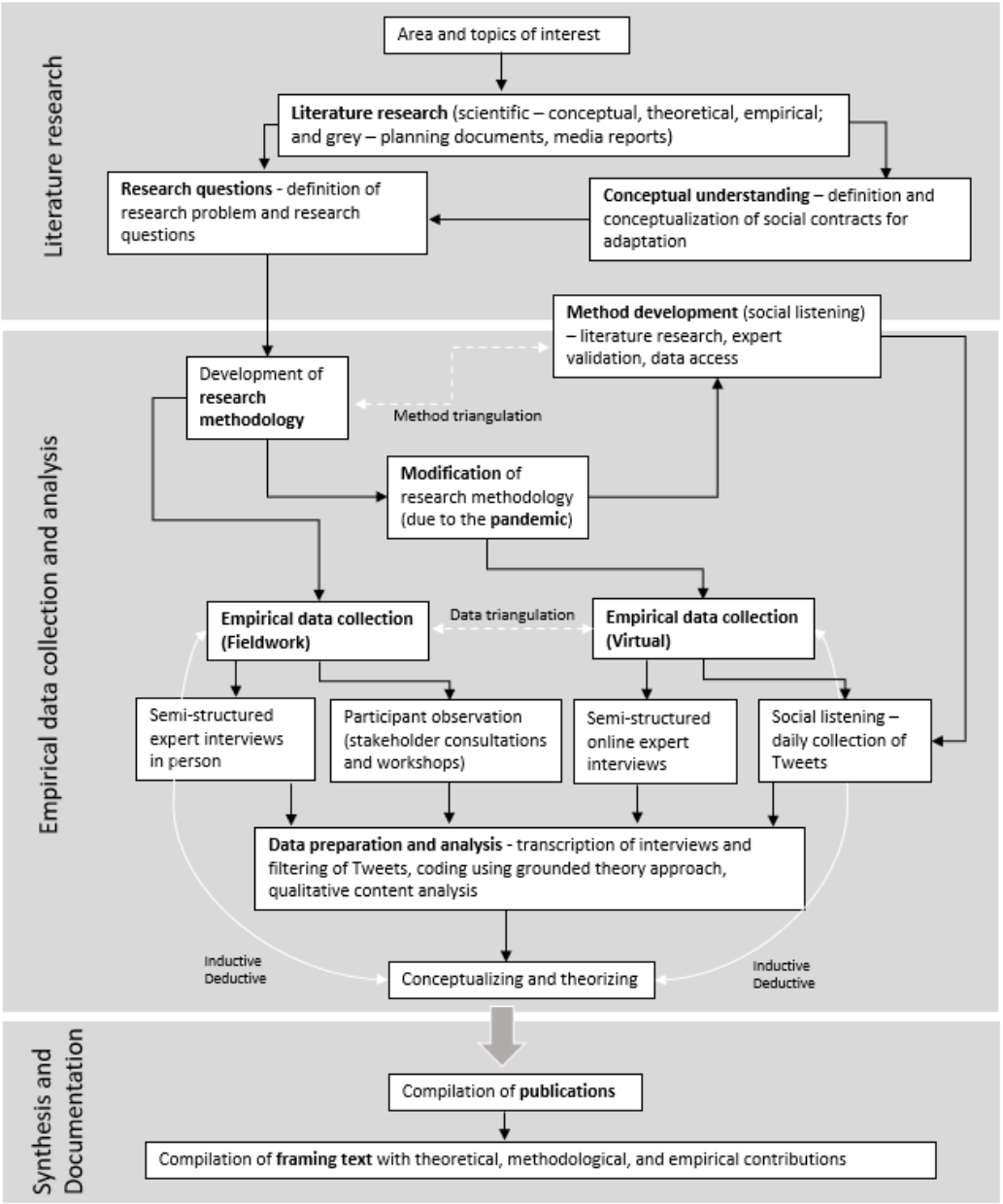
I believe my ability to move along the insider-outsider continuum brought certain advantages and potential disadvantages. My positionality has possibly influenced the data collection in the case of expert interviews. For instance, my appearance of being Indian, female, and seemingly young, in interviews with most experts who were mostly older, Indian, and male, may have resulted in me not being taken seriously. However, I tried to address this potential bias upfront and briefly explained my academic credentials at the beginning of the interview, which potentially influenced the dynamics. Yet, it is impossible to be fully aware of how others construct my identity and if and how this may have influenced their responses. During interviews, a shared cultural background may have facilitated ease of communication – both verbal (e.g., switching between languages) and non-verbal cues (e.g., head movements play an important role in communication in India, proved to be particularly helpful when wearing an FFP2 mask or only being able to see each other's faces over virtual interviews). It potentially allowed me to ask more meaningful and insightful questions due to having previous knowledge and secure more honest responses because of more trust, thereby allowing me to produce a more authentic and "thick" description (Geertz, 1973).

In contrast, though, in the case of social listening, I could take myself out of the equation, at least in the data generation and collection phase of the research. In other words, I was not explicitly involved in eliciting the data (users' act of posting Tweets and the content of Tweets has been independent of my research). Social listening allowed me as a researcher to observe social interactions on the platform without myself being actively involved or influencing the users in their communication. Owing to my cultural background, I am aware of the advantages in the interpretation of the data it may have brought in being able to understand the language, colloquial terms, nuances, and sentiments expressed in Tweets.

Hence, it is important to acknowledge, that being embedded and influenced by social processes, I will never be able to objectively describe reality. Despite striving to be as neutral as possible, it is acknowledged that my research will be influenced by my positionality as a researcher and can thereby never be entirely 'objective' or 'neutral'.

3.3 Research design

Following the epistemological stance of this study, it combines a mix of qualitative and quantitative methods as well as deductive and inductive approaches across different stages of the research process (Figure 5).



Black arrows indicate the workflow. White arrows show triangulation and feedbacks in the grounded theory approach

Figure 5: Research design

Previous scientific literature has informed the understanding of the research problem, developed the rationale, guided the research questions for the analysis, conceptual and theoretical framing, and interpretation of the findings. However, following the paradigmatic approaches of this study, it did not serve to generate a hypothesis that was only required to be tested top-down. Instead, the research placed a major emphasis on the bottom-up, inductive elements and insights generated from the data itself to allow for theory development from the "ground" (Strauss & Corbin, 1998). While Strauss and Corbin's approach to grounded theory has largely influenced my research design

and the data collection and analysis of interview data, I found Charmaz (2005)'s interpretivist approach particularly useful in the method development and application of social listening using Twitter data (for the context of this study, I will refer to it as Twitter since this was how it was called at the time of data collection and analysis). Following constructivist ideas, Charmaz's (2005) approach allowed more flexibility and emphasis on the individual views and sentiments expressed in Tweets. Hence, the research followed a 'grounded theory' approach in theorizing, which is reflected in the stages of data collection and analysis (more details on how it guided the coding process are in section 3.4.1). Furthermore, resulting from the philosophical assumptions of this study, the different stages of the research (data collection, analysis, and conceptualization) did not follow a linear process but instead a cyclic process – known as 'hermeneutic circle' wherein "continual interpretation and reinterpretation" of interview data and tweets (Bernard, 2012, p.19) informed the research design. This nature of inquiry helped me to arrive at a more robust and valid interpretation of the data.

In keeping with the paradigmatic assumptions, this study adopted a mixed and multi-method research approach (MMMR). A mixed methods research design involves the blend of qualitative and quantitative research methods to provide a more complete understanding of the problem (Hesse-Biber & Johnson, 2015). In this study, a mix of qualitative and quantitative elements was particularly useful in the development of 'social listening' and the analysis of Twitter data (more detail in section 3.4.1). This required navigating unfamiliar territory and crossing disciplinary boundaries (media and communication studies, Big Data analytics, social media analysis) but also provided fertile ground for the development of a mixed methods approach. This is also part of the reason why mixed-methods research has acquired prominence – by providing flexibility in approaching complex issues and drawing on different types of methods and data by attempting to gain a more comprehensive understanding of the research problem (Hesse-Biber & Johnson, 2015). The rationale for a multi-method research design was to generate a more robust, valid, and comprehensive understanding of the research problem. Each method brought its own strengths and weaknesses, for example, concerning multiplicity of viewpoints, depth of information, solicited vs unsolicited data, time frames, speed, and cost of data collection. Yet, together, they complemented each other to provide a better understanding of the broader research problem.

The use of a multi- and mixed-methods research approach, broadly, as well as in this study, is also to conduct a method triangulation (Denzin, 2015). The primary reasons for method triangulation are to avoid the pitfalls of a single method or scientific approach (qualitative or quantitative) on the one hand and, on the other, to acquire a more robust understanding of the problem. This study also conducted data triangulation, collecting both qualitative and quantitative data. Furthermore, due to the element of method development involved in the use of 'social listening' in this study, it was necessary to conduct a hybrid form of "method and researcher" triangulation. This involved a series of interviews with experts across different disciplines (from media and communication studies, computer science, data science, social media studies) to validate and cross-check the method.

3.3.1 Adjustments to research design due to the Covid-19 pandemic

The research design underwent significant challenges and resulting changes due to the COVID-19 pandemic. The kick-off workshops for the TRANSCEND project, which were planned for February-March 2020 in Jakarta and Mumbai, were postponed on very short notice due to the rapidly developing pandemic situation in both countries. A week later, complete lockdown was declared in

Germany. The COVID-19 pandemic had a major impact on the research design of this PhD study. This sub-section outlines the key adjustments that were made to adapt to the pandemic.

Some key decisions that influenced the research design had to be taken due to the pandemic.

First, due to travel restrictions, it was decided to switch to virtual interviews and reach out to experts via E-mail requesting an interview over Zoom. However, this proved to be very difficult as I received very low responses to invitation requests via E-mail. The kick-off workshops would have played a key role in establishing contact with key stakeholders, presenting the project in which my PhD research is embedded, and introducing team members. These contacts were of vital importance for identifying and establishing contact with potential experts for the planned semi-structured interviews in both countries. Another potential reason for the low response could have been that the timing eventually coincided with the unforeseen development of the deadly second wave of the pandemic in India that had resulted in over 274000 deaths and 26.4 million confirmed cases by May 2021 (Balsari et al., 2021). Stakeholders had different priorities and concerns and it felt insensitive to send follow-up requests and burden interviewees to volunteer their time for a research project during this difficult period.

Second, an important method planned as part of the pre-pandemic research design that could not be conducted due to the travel restrictions was household surveys with flood-affected households in Mumbai. However, this limitation forced me to think creatively about data collection and more innovative approaches (see below). Furthermore, in the meantime, it was possible to conduct household surveys within the TRANSCEND project in May 2023. Triangulation of the findings from this research with the household survey data is a planned next step of future research.

Third, overall, the inability to travel to the field and conduct fieldwork, unsuccessful virtual interviews, and huge uncertainty about the future due to changing rules, vaccine development, and new variants. To address this barrier posed by the COVID-19 pandemic of not being able to travel for fieldwork, I turned to explore the use of Twitter data as an emerging 'marketplace' of opinions and the development of social listening as a method to assess social contracts. While this decision was taken out of necessity and the uncertainty of when it would be possible to travel for fieldwork, social listening turned out to be a novel and insightful approach to assessing social contracts.

Fourth, in the pre-pandemic research design, I intended to conduct a comparative study between Mumbai and Jakarta (the two case studies of the TRANSCEND project). However, due to the pandemic I decided to start the empirical work (both in the case of the virtual interviews and social listening) with the case of Mumbai, given my familiarity with the context and the increased likelihood of being able to travel there as soon as it would be possible (due to having an Indian passport and not being dependent on a research visa, as would have been the case with Jakarta). As it already became possible to travel to Mumbai in September 2021 (after vaccinations and lifted travel restrictions, yet at my own risk), I decided to focus only on Mumbai. As it only became possible to travel to Jakarta in the middle of 2022, I plan to transfer the methodological approach of this study to Jakarta in future research.

Fifth, while it was possible and considered safe (after being vaccinated) for me to travel to the field in September 2021, eighteen months after originally planned, our local project partners continued to advise against conducting household surveys during that time. Not only did it present logistical challenges of organizing fieldwork in Mumbai during the pandemic, but it was also postponed in cognizance of the burden that vulnerable households were already experiencing due to the challenges of the pandemic. Hence, on the advice of the project partners, I decided to focus

only on conducting expert interviews due to the higher possibility of adhering to COVID-aligned safety protocols. Nevertheless, I had to travel at my own risk and was allowed to enter India because of my citizenship.

Finally, conducting fieldwork at the pandemic's peak brought its own challenges. It was necessary to constantly monitor the development of the pandemic and its variants, follow strict hygiene protocols for traveling from Germany to India, and closely track travel restriction updates. Furthermore, it became difficult in the field to balance taking utmost care and following safety regulations (social distancing, well-ventilated, and with a mask if indoors) with the on-the-ground realities of building trust and establishing contact with an FFP2 mask. I shared a personal account of this experience in a blog on the TRANSCEND project's website. (Doshi, 2022).

3.4 Methods adopted in this study

Against this background of the research design and its adjustments due to the COVID-19 pandemic, the study adopted the following main methods – social listening, semi-structured expert interviews, and participant observation, which are described in this sub-section.

3.4.1 Social listening

The era of digitalization, big data, machine learning, and artificial intelligence, has transformed the capacity to collect and analyze large amounts of data in natural and social sciences. Several types of big data exist and hold potential for adaptation research, including, geospatial big data, cell phone records etc. However, in the context of this study, I focus on the value of social media data (SMD). Owing to its volume, speed, and scale, social media data offers many advantages for urban adaptation research and decision-making. Many studies on urban climate change adaptation and related fields of disaster risk and sustainability have used different types of SMD across platforms such as Twitter, Facebook, Instagram, Flickr, and TikTok (Andreotta et al., 2019; Ilieva & McPhearson, 2018; Kirilenko et al., 2015).

Twitter has been one of the most popular data sources for research among social media platforms[1] due to its ease and scope of access through a variety of Application Programming Interfaces (API). Twitter is characterized by a unique network topology of openness which allows users to follow any registered user. The short text limit of 140 characters and social network properties of re-tweeting, searching hashtags (#) to follow and start topical debates and digital movements as well as mentioning (@) other users allow rapid sharing and engagement globally. Studies have employed a range of quantitative (e.g. descriptive statistics, correlation, regression, cluster analysis, Natural Language Processing techniques, and Large Language Models) and qualitative methods (e.g. content analysis, social network analysis, semantic analysis, and thematic analysis). Studies have used geotagged Twitter data in combination with qualitative content analysis, for example, to understand socio-spatial interactions in the aftermath of Hurricane Sandy (Shelton et al., 2014) and track social activity during disasters such as earthquakes using machine-learning methods (Mendoza et al., 2019) and floods. Some studies have also used Volunteered Geographic Information (VGI), for example, to

[1] Changes in regulations of Twitter (now X) from mid-2023 which was after the data collection and analysis for this study had been completed, might affect the popularity and use of X for research.

locate local shelters for informing disaster response (Kusumo et al., 2017) and to identify local flood hotspots in Mumbai (Tripathy et al., 2024).

Another popular method includes conducting 'sentiment' analyses using algorithm-based techniques such as Natural Language Processing, for example, to analyze 'happiness' in Tweets on climate change (Cody et al., 2015), perception of 'smart cities' projects in African cities (Arku et al., 2022) or assess public sentiment on the relocation of Jakarta (Sutoyo & Almaarif, 2020). Studies have also used qualitative methods to assess sentiments, for example, (Roberts et al., 2019) evaluated emotional responses to urban green spaces manually confined to six overarching emotions, and (Eslen-Ziya, 2022) qualitatively analyses narratives of environmental concerns in Turkey. Other qualitative methods for analyzing Twitter data include content and thematic analysis, such as discourses on hurricanes (Jacques & Knox, 2016).

In view of the vast potential of big data, including social media data, previous studies suggest that it has been underutilized in climate change adaptation research, including in cities (Archibald & Butt, 2018; Balogun et al., 2020; Ford et al., 2016; Sarker et al., 2020). At the same time, there is a need for new data and tools to capture complex urban dynamics, advance urban science, improve our understanding of "complex social-ecological-technological interactions in cities" (McPhearson et al., 2016, p.206), and support decision-making towards more sustainable urban futures (Ilieva & McPhearson, 2018). Ford et al. (2016) argue that big data, when used with caution, could "revolutionize" (p.10729) risk management thinking and present an "opportunity gap waiting to be filled" (p.10732). Hence, against the background of the wealth of studies that have utilized Twitter data, including in climate change-related research, this study builds on previous literature to use Twitter for assessing social contracts for adaptation to flood risk in Mumbai.

This study adopted and built on the approach of social listening, which has been defined as an "active process of attending to, observing, interpreting, and responding to a variety of stimuli through mediated, electronic, and social channels" (Stewart & Arnold, 2018, p.86). Adopting a grounded theory approach, I combine the inductive exploration of data to capture the dominant debate on Twitter with a deductive application of a social contracts theoretical lens. In line with the conceptual and theoretical focus of this study on social contracts, social listening as a method was explored to assess the different opinions and interactions between different actor groups. Given the exploratory nature of method development in the context of this study, next to a targeted literature review and self-learning of methods in social media analytics, I sought expert validation by conducting semi-structured expert interviews with experts across different fields of computer and data science, media and communications and social media and Twitter research more specifically. Experts were identified through key publications and snowballing.

Twitter forms an increasingly important digital marketplace to capture the exchange of opinions of different stakeholders. Furthermore, they are unsolicited by the researcher thereby minimizing their own influence on the data generation. In this regard, social listening also proves to be a novel method to capture the tacit and very implicit dimension of 'imagined' social contracts which are methodologically hard to capture. Another significant advantage and rationale for using Twitter data, in addition to complementing this study with semi-structured expert interviews, was the possibility of capturing the entire debate on flood risk in Mumbai defined by the key hashtags and keywords. Moreover, Twitter was also carefully chosen for the context of this study on Mumbai under

the following considerations. In comparison to other countries, India has the third-largest number of active users on Twitter followed by the United States and Japan (Statista, 2024c). “The debates on Twitter are generally very open, in line with the long tradition of the country’s free speech and backed by The Indian Constitution which guarantees all citizens the fundamental right of “Freedom of speech and expression” in Article 19” (Doshi & Garschagen, 2023a; Government of India, 1950).

To gain access to Twitter data, I successfully applied for a Twitter Research Fellowship. The Fellowship enabled “academic access” to the entire archive of Twitter data going back to 2006 (however, in this study I was primarily interested in capturing real-time data over the monsoon season of 2021). The API access allowed me to retrieve all flood risk-related Tweets on Mumbai using R. I triangulated the method of Twitter data collection using MAXQDA’s (a qualitative data analysis software) Twitter API in the first week of the monsoon season (01. June – 07. June 2021). Having received the same set of Tweets through both R and MAXQDA, I decided to continue with MAXQDA for the entire period of data collection (01. June – 30. September 2021) to allow for easier synchronization and qualitative coding in future steps of the data analysis. Data was collected through specific hashtags and keyword combinations. The initial list was verified by an expert on Twitter research in the context of disaster risk in India (including flood risk in Mumbai). The list was carefully monitored and refined over the first four weeks of data collection for any new, emerging and popular hashtags and keywords relevant to the monsoon season of 2021 (e.g. #monsoon2021) or those that did not receive any hits were deleted. Furthermore, to maintain consistency, data was collected at regular intervals at the same time (~2 PM CET/ 5:30 PM IST) (based on expert advice). In total, I collected all flood risk related Tweets on Mumbai using the list of specific hashtags and keyword combinations (~ 70,000 Tweets, including 20 variables of metadata such as retweets, likes, number of followers, language, etc. for each Tweet, thereby resulting in a dataset of 1.3 million values of metadata). While quantitative methods are often used in analyzing social media data, it is also important to be cautious of the size of these datasets and, thereby, their influence on statistical power. Hence, in this study, quantitative analyses using descriptive statistics were only used to describe the profile and composition of participants in the dominant debate. However, the primary focus and knowledge gain is from the qualitative analysis of Tweets. Following the grounded theory approach mentioned above, this study combined an inductive exploration of Twitter data with the deductive application of a social contracts theoretical lens.

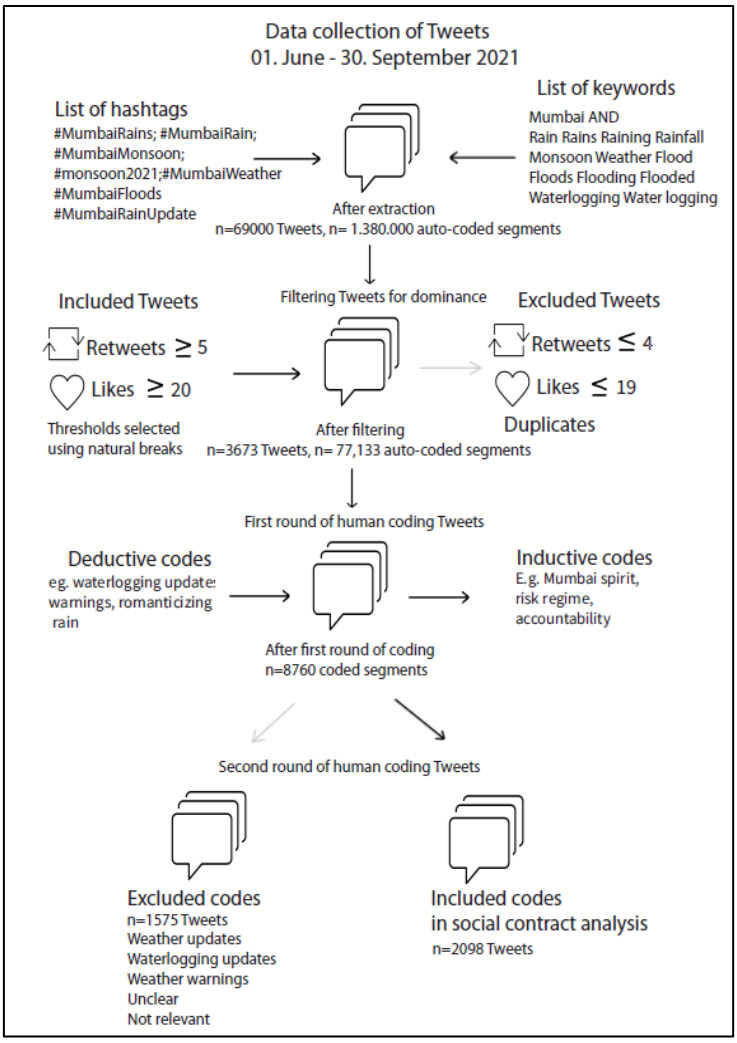


Figure 6: Flowchart of steps undertaken in Twitter data collection and analysis

Source: (Doshi & Garschagen, 2023a)

In a nutshell[2], the Tweets were filtered for dominance, defined by high levels of engagement through re-tweets and likes, which resulted in ~3600 dominant Tweets. These Tweets were then manually coded to show which actors participated in the dominant debate and the major themes that emerged. Subsequently, the dataset was filtered for codes that were most relevant to the social contracts analysis (around two-thirds of the total) which were then analyzed in more detail (for example, which dominant themes emerged, actors' expectations on roles and responsibilities for flood risk management, ascribed actors etc.). The qualitative coding follows the principles of qualitative content analysis, informed by a grounded theory approach wherein deductive codes were developed using a social contracts theoretical lens. However, inductive coding allowed the

[2] For a more detailed overview of the method, including steps taken such as data collection, filtering and coding, please refer to the Methods section of Doshi and Garschagen 2023a, p. 8-9 and Supplementary Material Table 3 or Table A1 in the Appendix for the qualitative codebook.

flexibility to identify topics and codes that emerged from the data. Figure 6 describes the main steps in the data collection and preparation.

To be fully transparent about what the method and data can and cannot do or show, the following paragraph outlines the main limitations and how I address them.

First, a major limitation of social media data is the limited information or metadata on the demographic composition of the participants. However, in this study, the language of the Tweet and the device used to Tweet (Apple, Android, or Web App) were taken as proxies for the socio-economic status of the participants. Furthermore, a manual coding of the Tweets and a description of their user accounts also allowed me to identify which actor group a Tweet belonged to, such as individual, state, media, and civil society.

Second, linked to this, another significant challenge in social media data is the representativity of populations. Participation on social media platforms is dependent on available and affordable access to the internet and digital literacy, which can largely vary across population groups and geographies. However, the demographic composition of Twitter users in comparison to the demographic composition of the geographical population of Mumbai is not inherently problematic in the analysis due to the nature of trans-local debates taking place on social media platforms such as Twitter. Nevertheless, it is important to consider that the composition of participants may be more likely to be from the urban elite and growing middle classes in comparison to vulnerable populations in informal settlements. However, this aspect is not perceived as a limitation per se as the middle class in India is a rapidly growing, aspirational, and disproportionately powerful class in society that shapes the socio-economic and political space (Mawdsley 2004) and their views in adaptation debates remain understudied.

However, the limitation of the method in not capturing the 'direct' voices of the vulnerable populations is acknowledged. Nevertheless, it does not exclude the possibility of the concerns of vulnerable populations being discussed in Twitter debates. Moreover, in future research, the findings will be triangulated with data collected through the household survey that was not possible to conduct in 2021 due to the pandemic (but later became possible as of May 2023). The household survey data will provide the ability to understand the 'direct' views of vulnerable populations as the survey was conducted in primarily informal settlements exposed to flooding.

Third, this study does not aim to provide a complete assessment of social contracts through social listening but instead aims to capture an important as well as potentially influential segment of this debate (e.g. among middle classes and elite) that takes place on virtual platforms such as Twitter. In this research, method, and data triangulation is performed by complementing the study with semi-structured expert interviews and participant observation.

Finally, it is important to note that while this study could access Twitter data through both – the academic access provided by Twitter as well as MAXQDA's Twitter API, changes made to Twitter API regulations as of April 2023 make it no longer possible to access Twitter data as easily. However, MAXQDA still allows the analysis of previously imported Tweets through its software. Reflections on this challenge of changing regulations regarding the access of social media data yet their growing importance and potential to understand societal changes are discussed in chapter 6 (cf. 6.4).

3.4.2 Semi-structured expert interviews (online and in-person)

In addition to social listening, semi-structured expert interviews were used to acquire in-depth, detailed contextual knowledge from selected key informants across different stakeholder groups. In total, I conducted 37 interviews that were used for the analysis in this study. Interview partners included key informants across primarily three actor groups - state, civil society, and academia working on flood risk management in Mumbai. State actors were selected due to their role as decision-makers and influential scope in driving the dominant risk management paradigm in the city. I interviewed actors from the local municipal authority (Mumbai Municipal Corporation of Greater Mumbai), the metropolitan planning authority (Mumbai Metropolitan Region Development Authority), and from the Maharashtra state government. Civil society actors were selected as they were seen to speak to the concerns of specific marginalized communities in the city and environmental concerns. Interviewees were largely working on issues of social justice for the urban poor and environmental protection. While civil society actors were taken as proxies in this study, it is important to mention that they might have their own political biases and agendas because of which they cannot be considered to represent the voices of the public. To address this challenge, the study adopted social listening to capture different opinions and will triangulate the study with household survey data as a future step of the research. Actors from academia were chosen because of their expertise and proximity to innovations and novel approaches to adaptation, ability to provide an overview on changes in flood risk management from the past to present as well as suggest directions for future adaptation. Interview participants largely came from universities and think tanks, including professors and senior researchers. Hence, the diversity of interview partners across different actor groups, scales and topics of focus, different roles and expertise, allowed for capturing a rich and insightful overview on flood risk management in Mumbai. An overview on the interviews conducted can be found in the Appendix (A5).

Key informants were identified based on an extensive desk-based literature review of scientific and grey literature including policy and planning documents, media reports, and newspaper articles. Additional experts were also identified in discussion with our project partner in Mumbai, who provided me with their contact information. For more details on the data collection process, please refer to (Doshi & Garschagen, 2023b), section 4.1. Initially, I had planned to establish contacts with key interview partners in the kick-off workshop to be held in March 2020 (which ultimately got postponed due to the pandemic and took place two years later in March 2022). Hence, data collection started with e-mail invitations for online interviews via Zoom. However, it proved to be very difficult to receive responses to the e-mails and only seven online interviews could be conducted over seven months.

Ultimately, a majority of the interviews were conducted in person in Mumbai between September – November 2021 when it was possible to travel again after being vaccinated, and in April-May 2022 after the kick-off workshop. Once in the field, it became easier to identify experts through snowball sampling when conducting in-person interviews. Acquiring the WhatsApp contacts of the interview partners played a key role in getting positive responses to interview requests. The fortunate coincidence of fieldwork in September-November 2021 with the development of the Mumbai Climate Action Plan allowed me access to many state actors, including some high-level officials in the municipal government authority. This access would not have been possible without the support of some key stakeholders as well as if I had not been there in person.

The interviews were conducted with the help of an interview guide which was meant to be used as guiding questions but allowed sufficient flexibility and room for relevant concerns of the experts and follow-up questions. The interview guide can be found in (Doshi & Garschagen, 2023b) in the Appendix as well as in the Appendix (Table A2) at the end of this dissertation. The interviews ranged between 25 minutes to 2 hours and on average between 35 to 40 minutes. They were conducted primarily in English with some expressions in Hindi, based on the expert's preference and comfort.

The interviews were transcribed partly with the support of a student assistant. All interview transcripts were transferred to MAXQDA. In cases where recording the interview was not allowed, interview protocols were used. Interviews were coded following a grounded theory approach, based on principles of qualitative content analysis and using deductive as well as inductive codes. The coding scheme was developed for two publications. The second publication focuses on the actor-oriented multi-dimensional evaluation of adaptation options identified by the experts and how they assessed them in terms of desirability and feasibility dimensions. For details on the coding steps, coding scheme, and analysis in the second paper, please see (Doshi & Garschagen, 2023b), section 4.2, and Appendix Tables A1 and A2. Several rounds of coding, or working in hermeneutic circles, allowed me to extract deeper meanings through the interview data and informed the development of additional codes that informed the coding scheme for the third paper (Doshi and Garschagen, under review). The main focus of the third publication is on actor-oriented desired objectives, target actors, and the distribution of roles and responsibilities for the identified adaptation options. For details on the coding and analysis of the third paper, please refer to Doshi and Garschagen, under review, Section 4 (cf. 5.3). Table 7 shows the research questions addressed through the interviews.

The data collection and sampling process faced several limitations.

First, the sample of interview partners was affected by multiple factors that may have resulted in biases and/or gaps in the data. The sample of interviewees for online interviews was severely constrained due to non-responsiveness to interview requests (cf. 3.3.1). However, I tried to address this challenge when it became possible to travel to the field in September 2021 and could meet with several of the interview participants I had reached out to online. For in-person interviews, the sample was also heavily determined by the accessibility to the partner (most successfully if I had the WhatsApp contact through snowballing) and their availability in terms of time.

Second, the interview process could have been influenced by contextual factors. Virtual interviews were comparatively shorter than in-person interviews which were on average longer and proved easier for engaging in in-depth follow-up questions. However, in-person interviews were sometimes influenced by external interruptions, e.g. phone calls, work-related requests, or other urgent matters (especially for state actors), whereas virtual interviews were surprisingly undisturbed.

Finally, the interviews may have been influenced by my positionality as a seemingly young, female researcher which I tried to address upfront by clarifying my academic background (cf. 3.2).

3.4.3 Participant observation

During my fieldwork in Mumbai, I had the opportunity to participate in several (by invitation only) internal meetings of the Mumbai Climate Action Plan at the municipal government authority as well as both in-person and virtual stakeholder consultations conducted in the course of the development of the Plan. I was also invited to participate in a two-day workshop exclusively on the topic of flood

risk in Mumbai, organized by the municipal government in collaboration with the state government. Several key experts and stakeholders were invited. Topics of relevance to social contracts including roles and responsibilities, prioritization of adaptation options, and their feasibility and desirability were discussed and contested by different stakeholder groups. Finally, I also participated in the two workshops organized in the frame of the TRANSCEND project – the kick-off workshop and the participatory scenario workshop in Mumbai. My notes and observations from these meetings and workshops helped to complement my findings from the other two methods in this study – social listening and semi-structured expert interviews.

Table 7 provides an overview of the methods and maps their contribution to the research questions and core publications of this dissertation.

Table 7 | Employed methods and their contributions to research questions and core publications

Data collection method	Data sampling and sample size	Time of data collection	Data analysis tools and methods	Contribution to Research Questions [a]	Contribution to Publications
Social listening through Twitter	-Search string of selected hashtags and keyword combinations yielded ca. 70,000 Tweets. -Filtered for dominance defined by high level of engagement through re-tweets and likes yielding ca. 3600 Tweets for in-depth coding	1st June – 30th September 2021 (according to the monsoon season in Mumbai)	-Access through Twitter API using R and MAXQDA -Qualitative content analysis in MAXQDA -Grounded theory approach – combined deductive coding informed by social contracts theoretical lens and inductive coding	RQ 1, 4 and 5	Publication I: Assessing social contracts for urban adaptation through social listening on Twitter
Semi-structured key informant interviews (online from Germany)	Literature-based and through local project partner N=7	-Invitations sent: December 2020 – January 2021 -Interviews held via Zoom between: May 2021- August 2021	-Qualitative content analysis using MAXQDA -Grounded theory; hermeneutic circles -Coding schemes focus: Publication II: evaluation of adaptation options for feasibility and desirability Publication III: Actors' objectives and roles and responsibilities	RQ 1-4	Contribution to Publication II: Ruptures in perceived solution spaces for adaptation to flood risk: Heuristic insights from Mumbai and general lessons AND Publication III: Actor-specific adaptation objectives shape perceived roles and responsibilities: Lessons from Mumbai's flood
Semi-structured key informant interviews (in person, except N=5 conducted online from Mumbai upon request)	Literature-based; local project partners; participant observation and snowball sampling N= 30	-September 2021- November 2021 -April 2022- May 2022		RQ 1-4	

Participant observation	-Meetings and stakeholder consultations for Mumbai Climate Action Plan -Two-day flood risk workshop -TRANSCEND Kick-off workshop -TRANSCEND participatory scenario workshop	-September 2021-November 2021 -April 2022 -November 2022	Field notes	RQ 2-4	risk reduction and general considerations

[a] Corresponds to research questions in Chapter 1, section 1.3

Table 7

To summarize, this chapter provided an overview of the methodological approach, highlighting the paradigmatic worldviews that guided this study, my positionality as a researcher, the research design including the necessary adjustments that I had to make due to the COVID-19 pandemic, and the individual methods of data collection and steps taken in the analysis. While the methodological approach is deemed suitable to answer the research questions for this study (Chapter 1, section 1.3), the chapter also acknowledges its potential limitations and how I tried to address them. Hence, this chapter aims to guide the understanding of the results (chapter 5) and contextualize the discussion of the findings (chapter 6) of this study.

Having selected the case study of Mumbai, the next chapter turns to give a brief overview of the context of flood risk management in Mumbai and why it was chosen as the empirical case for this research.

4. CASE STUDY: FLOOD RISK MANAGEMENT IN MUMBAI

This chapter will provide a brief background with details that argue for the relevance and importance of Mumbai as a case study in the context of this dissertation on social contracts for adaptation. The first section describes Mumbai's complex and changing flood risk in terms of its drivers – including hazard trends, changes in exposure, and vulnerability (4.1). The subsequent section describes flood risk management measures undertaken by different actors, including state and non-state (4.2).

4.1 Drivers of flood risk in Mumbai

Mumbai, with an estimated population of 21 million (Mumbai Metropolitan Region), is the ninth-largest city globally (United Nations, 2019b). With an average population density of 83,660 people per square mile, it is one of the densest cities in the world (World Population Review, 2024). It is India's financial capital and an engine of economic growth in South Asia, by being a substantial contributor to the country's GDP and almost a third of total tax revenues (David, 2019). Mumbai is characterized by high socio-cultural diversity due to high rates of migration. It shows high socio-spatial fragmentations along lines of income, religion, class, caste, and tribe (Shaban & Aboli, 2021). On the one hand, almost 40% of the population lives in informal, slum settlements, yet occupy 6% of the land area (Census of India, 2011; Goudet et al., 2018). On the other hand, it has a growing aspirational urban middle class and a small, yet powerful urban elite that lives in high rises. The widening gaps in incomes and lifestyles and continued marginalization of the urban poor render steep gradients in the vulnerability and adaptive capacity between different groups (Gandy, 2008). Vulnerability is shaped by complex socio-economic factors deeply rooted in the political economy of urban development (Parthasarathy, 2016c). This makes the question of how future vulnerability and adaptive capacity trends will develop quite uncertain yet very important.

The following sub-sections provide an overview of the major drivers of flood risk in Mumbai, structured along the three components of risk: hazard, exposure, and vulnerability.

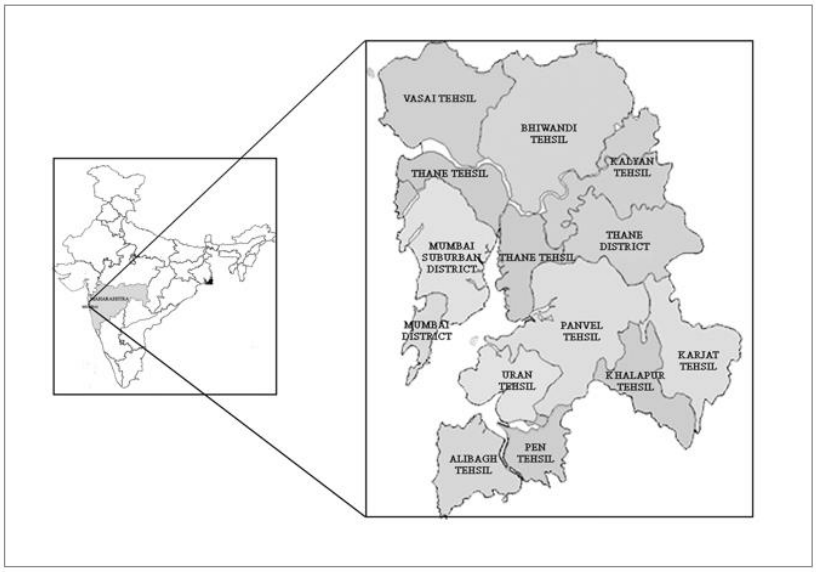


Figure 7: Geographic location of Mumbai (left) and districts of Mumbai Metropolitan Region (MMR) (right)- Mumbai District and Mumbai Suburban District constitute Greater Mumbai (Source: Sahu & Saizen, 2018)

4.1.1 Drivers of hazard

Looking at the city in its current form, it might be hard to imagine that this dense, concretized megacity evolved from an agglomeration of a few islands (Riding, 2018). Located on the northwestern coast of India, with the Arabian Sea to its west and separated from mainland India by a narrow creek to its East, it is therefore also known as the 'island city' (ibid.) (Figure 7). The geography of the city, i.e. its islands – which later played a central role in the city's planning was heavily contested during its transfer from the Portuguese to the British in 1664 (ibid.). The map below in Figure 8 illustrates the coastal and island geography of the city in its regional context. Although heavy precipitation and associated flood events are almost an annual phenomenon during the southwest monsoon season between June and September every year, their intensity and frequency have increased in recent years. Mumbai is also facing an increase in the intensity of tropical cyclones in the Arabian Sea (Abhiram Nirmal et al., 2023; TERI, 2014). Furthermore, the coincidence of heavy rainfall with high tides can exacerbate the intensity of flooding, leading to flash floods (as occurred in 2005). The nature of flooding can be fluvial, pluvial, tidal, or coastal, and in the case of extreme events, flash floods can also occur (most recently in 2021 and 2022)(Firstpost, 2022; The Indian Express, 2021; The New Indian Express, 2021). Finally, as a low-lying coastal megacity, Mumbai is also currently and increasingly in the future at risk to the impacts of climate change – sea level rise being the most notable one (Pramanik, 2017). The combined effects of sea-level rise, high tides, and floods could amount to damages in the range of USD 49-50 billion (Abadie et al., 2020).

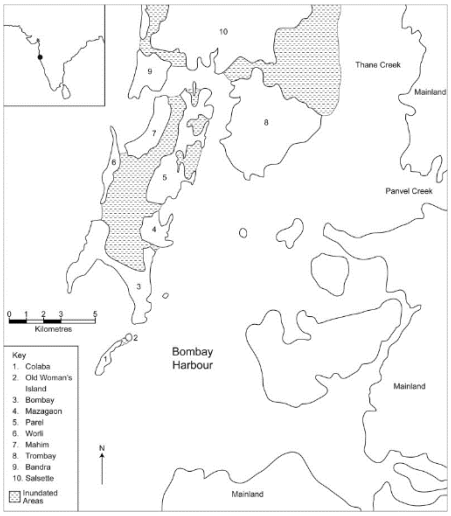


Figure 8 Map of Bombay islands, Source: (Riding, 2018)

Mumbai experienced its most catastrophic flooding in July 2005, when it received one-third of its annual rainfall in 24 hours, which resulted in a loss of almost 1500 lives and a financial loss of USD 1.7 billion (Bhagat et al., 2006; Conservation Action Trust, 2005; Revi, 2005). Flood events in the past have resulted in the loss of over 400 lives over the past decade (Srivastava, 2021), e.g. triggered by landslides leading to collapsed houses in informal settlements (The Times of India, 2021), collapsed walls (BBC, 2019), electrocution (BBC, 2021), and drowning. Flooding has also led to major disruptions in critical infrastructure such as access to clean drinking water, sanitation facilities, and transportation, and immense damage to housing, vehicles, and other assets. Long-term impacts include disruption to livelihoods, temporary displacement, health (leptospirosis, dengue, malaria,

and other water- or vector-borne diseases) (Chouhan et al., 2017; De Sherbin & Bardy, 2016; Dhiman et al., 2019; TERI, 2014).

4.1.2 Drivers of exposure

The island city of Mumbai contains many low-lying areas that are highly flood-prone (Pramanik, 2017). Mumbai ranks amongst the top ten coastal megacities globally with high exposure to coastal flooding in terms of both population and assets (Nicholls et al., 2008). The study shows that even in future rankings, Mumbai remains among the top ten cities exposed (in terms of population) to coastal flooding (by the 2070s), expected to be only second, after Kolkata (ibid.). Furthermore, damages due to the impacts of sea level rise are expected to range between USD 49-50 billion by 2050 and potentially increase by a factor of 2.9 by 2070 (Abadie et al., 2020).

A major driver of exposure to flood risk lies in the city's historical physical transformation through extensive land reclamation (Adam et al., 2021). Originally a cluster of islands, the city in its current form has evolved through a series of massive, large-scale reclamation projects initiated during the colonial period and further increased post-independence in 1947 (Mumbai Transformation Support Unit, n.d.). An in-depth historical account of the physical transformation of Mumbai and how it has led to path-dependencies in urban planning is beyond the scope of this dissertation but is a part of another manuscript currently under preparation (Garschagen et al., in prep).

Several studies have confirmed the correlation between flood hotspots and reclamation zones (Mendiratta & Gedam, 2018; Murali et al., 2020; Sansare & Mhaske, 2020). The process of land reclamation increased exposure to flooding in the following ways. First, the increase of dense, built-up areas in natural drainage basins and flood plains of the city heavily influenced the hydrological landscape of the city by increasing surface run-off and limiting percolation (Gupta, 2007; MCGM, 2017; Sansare & Mhaske, 2020). Second, large parts of the reclaimed new land were just above sea level and below high tide level, making these areas highly exposed to flooding during high tides (Dhiman et al., 2019; Gupta, 2007; Hallegatte et al., 2010). Third, the relation of reclamation to increasing exposure to flood risk lies not only in the reclaimed new land but also in what was (and is getting) lost as a result of the reclamation i.e., natural ecosystems such as mangroves, coastal wetlands, mudflats, salt pans and creeks, which act as important buffers against flooding when there is heavy rainfall and during high tides (Conservation Action Trust, 2005; Parthasarathy, 2016a).

The city's exposure is shaped not only by physical but also by socio-economic factors that drive people to live in highly exposed areas (Adam et al., 2021; Dhiman et al., 2019; Gupta, 2007; Hallegatte et al., 2010; Revi, 2005). Examples of these drivers can be found across both extremes of the socio-economic classes – from the elite who voluntarily live along the coast in expensive sea-facing apartments to the marginalized and poor forced to live along drainage lines and hill slopes. Further, the construction of several infrastructure projects and large resettlement and rehabilitation projects on the reclaimed land put people and assets at risk (Jha, 2020; Mendiratta & Gedam, 2018). Many slum settlements along the coast are highly exposed to coastal flooding, erosion, and strong winds from tropical cyclones (Municipal Corporation of Greater Mumbai, 2018). Landslides triggered by heavy rainfall also pose a high risk to many slum settlements located on hill slopes or foot of the hills and have been a major cause for loss of lives and damage to property in the past (Ellis-Petersen, 2021). Hence, the hybrid nature of exposure can be observed in the city of Mumbai, i.e. changes in exposure through physical and socio-economic factors (Garschagen, 2014).

4.1.3 Drivers of vulnerability

Combined with the physical exposure of many settlements and assets in flood-prone areas is the high physical vulnerability of informal slum settlements, which are often not able to withstand the impacts of heavy precipitation and strong winds (Patankar, 2015; Patankar & Patwardhan, 2016). In the most severe cases, collapsed houses have caused many deaths in past flood events (The Indian Express, 2021). Besides settlements, the city's vast transportation network including its railway line – also known as the lifeline of the city that brings thousands of commuters in and out of the city and the road network congested with two and three-wheelers are also heavily affected by flooding (BBC, 2022; BBC News, 2017; Firstpost, 2023).

The main driver of flood risk in Mumbai is its socio-economic vulnerability – especially for nearly half of its residents who live in temporary, informal settlements and face multifaceted marginalities stemming from social, economic, cultural, and political factors (Chatterjee, 2010b; De Sherbin & Bardy, 2016; Romero-Lankao et al., 2016). A major driver in the creation of the large informal sector and the persistence of slum settlements can be traced back to the introduction of neoliberal policies in the 1990s (Aggarwal, 2012; Nijman, 2007). This was accompanied by an increased reliance on the private sector and at the same time, social and economic marginalization in major Indian cities, including Mumbai (Nijman, 2008; Parthasarathy, 2003). This shift coincided with another important development in Mumbai – the closing down of textile mills, which was responsible for Mumbai's economic success before the 1960s (Chatterjee, 2010a). This led to large-scale social and spatial displacement. A large proportion of the manufacturing workforce had to eventually find employment in the informal sector (Patel, 2003). Furthermore, they were pushed out of the central areas to the margins so that the land on which mills stood could be allocated to lucrative and competitive activities in the global economy (D'Monte, 2006). The decline of the manufacturing sector and parallel rise of the service sector led to large informal employment that has increased the vulnerability of the workers through for example, lower wages and lacking access to social security. The lack of adequate formal employment opportunities is linked to the persistence of slums and informal settlements (Banerjee-Guha, 2002).

Geographically marginalized, such settlements are found across the city, for example, along the coast, in low-lying areas, along hill slopes, polluted drainage lines, and railways (Parthasarathy, 2009). These populations are disproportionately affected by the adverse effects of flooding not only due to their physical exposure to flood events but compounded by socio-economic factors such as low income, precarious livelihoods and living conditions, limited access to basic civic infrastructure and services such as waste collection, sanitation facilities, and legal electricity connections. (De Wit, 2016; M.-H. Zérah, 2008). A heterogeneous mixture of characteristics that typically contribute to heightened vulnerability is through, for example, migrant backgrounds, caste, religious minority, gender, non-fixed or contractual income, in combination with one or more of the challenges described above (Jha et al., 2015; Singh, 2020). Recurrent flooding not only damages their houses and goods by water entering inside but also the contaminated water leads to a range of adverse impacts on health and well-being (Adam et al., 2021; Chatterjee, 2010b; Parthasarathy, 2016c). Other typical impacts include loss of workdays, access to safe sanitation and transportation services and infrastructure during flooding (Hallegatte et al., 2010). Moreover, not only are the most marginalized sections of society heavily impacted by flooding but often also blamed and held responsible for causing waterlogging – leading to forced eviction (Conservation Action Trust, 2005; Hindustan Times,

2019; Patel et al., 2002). Furthermore, many slum settlements, not legally notified, are further subject to resettlement and forced evictions and often suffer from poverty, social exclusion, and marginalization – making them highly vulnerable (Hallegatte et al., 2010; Revi, 2005; Virani, 2022b).

The recent Covid-19 pandemic further exposed the heightened vulnerability of slums and informal settlements which bore not only the burden of compounding risks from flooding and the pandemic but also identified as virus hotspots and instead became the target of containment policies that threatened their livelihood. For example, the lockdown or social distancing measures in highly dense slum settlements meant 4 to 5 persons living in tin-roof houses of 8 by 10 square feet were expected not to leave the house (Bhide, 2021; Bhide & Kamble, 2020; Pattaroni et al., 2022). Despite being neglected, their absence was starkly felt during the migrant crisis triggered by the pandemic. The workers such as electricians and sanitation workers, who kept the city functioning during the monsoon – "cleared the drains of silt so that the rains don't cause flooding and water-borne diseases such as leptospirosis", many of whom were migrant workers and exited the city during the pandemic (Dhillon, 2020). Therefore, the confluence of the pandemic and flooding during the monsoon revealed the irony of the vulnerable – on the one hand, they are blamed, regarded as "encroachers," and held responsible for waterlogging, and on the other, the city cannot do without them.

Closely interrelated to the above drivers of socio-economic exposure and vulnerability are factors such as inadequate flood risk management, poor and exclusionary disaster governance, and lack of inclusive urban planning and development (Parthasarathy, 2016a, 2016c; Pattaroni et al., 2022; Shaban & Aboli, 2021; Weinstein, 2019). For instance, the destruction and pollution of mangroves have a detrimental impact on the livelihoods of thousands of fisherfolk living along the coast (Chouhan et al., 2016). Against the background of globalization, Mumbai became established as the country's financial capital and link to the global economy (David, 2019; Patel, 2003). This led to increased privatization and prioritization of commercial interests (Banerjee-Guha, 2002). A large number of infrastructure projects and interventions (construction of the Bandra-Worli Sea Link, widening of the Western Express Highway, diversion of the Mithi River for the expansion of the airport runway, and most recently, the ongoing construction of the Coastal Road) have been cited in the literature to have played a role in exacerbating past and potential future flood risk (Singh, 2023; The Indian Express, 2022). Despite strong protests against these projects due to their envisioned detrimental impact on the social, economic, and ecological vulnerability of Mumbai, they succeeded (EPW, 2015; India Today, 2022; Mumbai Mirror, 2019). Development plans, policies, and regulations have been consistently shown in the literature and critiqued in the media by practitioners, civil society members, and academics for their ignorance of environmental and equity considerations (Movik et al., 2023; Parthasarathy, 2016b; Pattaroni et al., 2022; Weinstein, 2019). Such contestations clearly illustrate conflicting priorities between different actors.

Hence, while the drivers of flood risk in Mumbai can be attributed to physical, climate change-related factors, it is also strongly influenced by the political economy of urban development and planning in the city.

4.2 Flood risk management in Mumbai

Despite the heavy pressure to adapt, studies show that adaptation action remains inadequate (Parthasarathy, 2016b; Revi, 2005; Singh et al., 2021). A study comparing the "adaptation economy" or spending on adaptation and resilience in different megacities, shows that Mumbai, like many

other developing country cities, spends ~ 0.15% GDPc (Georgeson et al., 2016). Furthermore, looking at the sectoral division of spending, similar to many other megacities, shows a strong emphasis on physical infrastructure-based sectors. This has also been referred to as "high modernism" (Scott, 1999) with a strong focus on technological "fixes", and engineering based approaches (cf. Dominant View in Chapter 2). However, the current models of adaptation in the city are highly contested, showing signs of diverging priorities, social fragmentation, and political turmoil. Every year during the monsoon, headlines such as "Mumbai will likely flood again – and nobody's doing much about it" (The Guardian, 2014), "Mumbai's Floods: A perfect storm of poor planning" (Bloomberg, 2017) or "Lessons Mumbai didn't learn" (The Indian Express, 2017), suggest that flood risk reduction measures are inadequate. In addition to the lack of adequate adaptation strategies in response to current and future flood risk, adaptation goals and the distribution of roles and responsibilities are also heavily contested and in part ambiguous (Adam et al., 2021; Bhide & Kamble, 2020; Movik et al., 2023; Parthasarathy, 2016b). The section below provides a background on the landscape of flood risk management in Mumbai.

4.2.1 Formal state-led adaptation efforts

According to the Disaster Management Act of India (GoI, 2005), core responsibilities for disaster management are ascribed to the state. However, previous studies have identified two major gaps: ambiguity on the responsibility of the state towards those affected by disasters (Chhotray, 2014) and resulting from this silence, a de facto implication of the legislation on the "active and willing support and cooperation of the local community" in disaster management (Pandey, 2016). According to this legislation, the district management authority is responsible for disaster management, which led to the creation of the Greater Mumbai Disaster Management Authority (GMDMA). However, in practice, there was an incoherence of the national legislation with the administrative landscape of Mumbai, which comprises two administrative districts. Hence, in 2017, the Bombay High Court dismissed the GMDMA and ordered the creation of two District Disaster Management Authorities (DDMAs) – one for Mumbai City and one for the suburbs. However, their de facto roles and responsibilities were questioned. In addition to this ambiguity, the Act is seen to implicitly entrust responsibility for disaster management in practice to the Mumbai Municipal Corporation of Greater Mumbai (MCGM) – a key stakeholder in flood risk management in Mumbai and responsible for overall civic infrastructure and services in the city. The MCGM is the richest civic authority in India in terms of the budget at its disposal (The Deccan Herald, 2023).

Formal flood mitigation strategies are dominated by physical infrastructural measures, advanced early warning systems, and rescue efforts in emergency operations (Municipal Corporation of Greater Mumbai, 2018). Within the MCGM, the Disaster Management Department is responsible for directing activities related to mitigation, prevention, and preparedness as well as management during flood disasters in both districts of Mumbai (Municipal Corporation of Greater Mumbai, 2018). It prepares the city's disaster management plan and annually releases 'Flood preparedness guidelines' for Mumbai (MCGM, 2017, 2021). The department is further responsible for emergency response and hosts the city's Emergency Operation Centre (EOC) and coordinates between different stakeholders such as the fire brigade and medical facilities (MCGM, 2021). Another ambiguity in the distribution of roles and responsibilities relates to emergency response. While the national legislation entrusts the district management authority with emergency management, the national level guidelines on urban flood management (UFM) regard citizens as first responders, prior to state action (GoI, 2005, 2010).

Given the importance of physical infrastructural measures in flood mitigation, the city's central flood risk management measure is the Brihanmumbai Storm Water Disposal System (BRIMSTOWAD) which was proposed in 1993 (MCGM, 1993) and falls under the responsibility of the MCGM under the Mumbai Municipal Corporation Act of 1888 (The Mumbai Municipal Corporation Act, 1888) . The storm water drainage system comprises 2900km of drainage built to a capacity of 25mm per hour, originally laid down by the British (MCGM, 1993). Another key component of the system is the stormwater pumping stations that have a capacity to pump out 6000 litres of water into the sea. Implementation plans of the BRIMSTOWAD project to increase drainage capacity to 50mm/hour remain incomplete (Government of Maharashtra, 2006). The inadequacy and ineffectiveness of the SWD system have been pointed out by the State Action Plan on Climate Change and its consequent impact on flooding (Sansare & Mhaske, 2020; TERI, 2014). The project is not yet completed, and barriers often cited in the literature include e.g. high costs, technical complications, and the presence of "encroachments" or households that live close to the drainage lines (Gupta 2007, Chitra 2022). A major implication of the BRIMSTOWAD project has been the relocation of households, with and without compensation (Anthony, 2022; Chatterjee, 2010a; Patel et al., 2002). While a key responsibility of the SWD department is the annual cleaning and desilting of the drainage system (Figure 9), media reports have pointed to the alleged corruption behind the process between contractors and politicians (Firstpost, 2017; Indorewala & Wagh, 2018). However, reports also point out the related challenge in waste management as the drainage lines are often clogged with solid waste or inaccessible due to the presence of informal settlements (Government of Maharashtra, 2006). Other formal measures for flood risk mitigation include, for example, anti-erosion barriers/ seawalls, underground holding tanks, and micro-pumps installed locally at flood hotspots (Figure 9) (Municipal Corporation of Greater Mumbai, 2018).

Figure 9 Physical infrastructure measures implemented by the state: Underground holding tanks (left) and drainage cleaning close to a slum settlement (right). Source: own

In addition to the Storm Water Drains department, other civic departments of the MCGM such as solid waste management, environment, roads, and traffic planning department, planning authorities such as the Mumbai Metropolitan Regional Development Authority, Public Works Department and state-level bodies such as Maharashtra Coastal Zone Management Authority (MCZMA), Maharashtra Housing and Area Development Authority (MHADA) are also directly or indirectly involved in different activities and measures related to flood risk management (Zimmermann et al., 2023). However, the lack of integration of plans and coordination between different departments and sectors leads to "balkanization" in the formal and institutional approaches to flood risk management (Parthasarathy 2016, p. 26). This has been pointed out as a major challenge for disaster governance in Mumbai

(Parthasarathy, 2016a). Adverse impacts of the lack of coordination between different departments, such as solid waste management and disaster management or physical division of the governance of the Mithi River between the MMRDA and MCGM, have major implications on the effectiveness of flood risk management. Similarly, fragmentation of governance for coastal ecosystems which play a major role in flood risk reduction is also a major barrier to ensuring their protection(Chouhan et al., 2016; EPW, 2015). For instance, the role of the Maharashtra Coastal Zone Management Authority has been criticized due to the steady weakening of the coastal regulation zone (CRZ) norms that threaten fragile ecosystems and livelihoods of coastal fishing populations who remain at risk of displacement. Simultaneously with the weakening of the CRZ is the increase in the Floor Space Index (FSI) that allows builders to redevelop the land along the coast and construct luxury housing with sea-facing apartments (Chouhan et al., 2018; Kapoor, 2020).

The city is now a member of the C40 Cities for Climate Leadership and launched the "Mumbai Climate Action Plan" (MCAP) in 2022, becoming India's first city to produce a climate action plan in cooperation with C40 cities network (MCGM, 2022). The Plan was formally launched with the support and endorsement of the Maharashtra state government and the MCGM. The governance of the plan also represents an emerging form of partnerships in climate change action more broadly, i.e. between the state, civil society actors such as nongovernmental organizations, academic institutions (local, national, and international) as well as private consultancies in the development of knowledge products, climate action plans, and workshops. In the case of the MCAP, the Plan was developed in cooperation with the international C40 cities network and international think tank organization World Resources Institute with stakeholder consultation including experts from the state, civil society, academia, and private sector (C40 Cities, 2022; Kanekar & Vaze, 2022). Urban flooding and water resource management are among the six priority areas identified in designing the city's roadmap to "a net-zero and climate-resilient Mumbai by 2050" (MCGM, 2022).

A closer look at the actions proposed for reducing flood risk however continues to rely on a technical, infrastructure-based approach that only addresses the hazard component of flood risk through drainage systems and rainwater harvesting (MCGM, 2022). In addressing the challenges of coordination and integration with other departments, the Plan calls for the establishment of a Climate Action Cell that would be hosted by the environment department of the MCGM (The Times of India, 2023). Although the Plan marks a commitment of the state to take formal action to address climate change, actors have questioned the consideration of equity aspects for the feasibility of the proposed measures as well as the level of transformability envisioned (Wagh & Indorewala, 2022). Critiques point out key concerns of social contracts for adaptation – whose priorities and targets are considered and for whose benefit.

Hence, overall, the extent to which formal flood risk management measures address the underlying drivers of risk and benefit the most vulnerable populations remains largely inadequate.

4.2.2 Flood risk management by non-state actors

Studies show that in the absence of formal flood risk management measures that effectively benefit vulnerable populations who mostly live in informal settlements, they often respond in the form of coping and autonomous adaptation (Chatterjee, 2010b). Strategies employed are mostly temporary, reactive, ineffective, and inadequate. Such measures are often the product of "jugaad", a commonly used term in Mumbai and northern India to refer to frugal innovation, "inventiveness, ingenuity,

cleverness or an improvised or jury-rigged solution" (Padukone, 2012, p.20). In an environment of scarce availability and accessibility to resources, the informal sector has been a driver of this "culture of adaptivity, frugality and thrift" (ibid). In popular debate, such innovation and ingenuity are praised in frequent combination with the "resilient spirit of Mumbaikars" that manifests in the ability of the city to bounce back quickly after any crisis or disaster. However, civil society has drawn attention to what the celebration of this spirit neglects – the helplessness of residents who potentially have no choice but to carry on with what they have (Firstpost, 2017) and the inadequacy of state-led formal support and action for adaptation (Adam et al., 2017).

Measures adopted at the household and neighbourhood level in informal settlements include both structural and non-structural. Structural measures at the household level include strategies such as raising the foundation of the house, building a second floor (primarily in higher-income households) or simply elevating a board or building an elevated platform in the house for storing valuables during a flood event (Figure 10) (Chatterjee, 2010b). At the neighbourhood level, local groups in some neighbourhoods would collectively widen and cover the drains to improve sanitary conditions in the settlement. However, structural measures have been questioned on their effectiveness in permanently reducing risk. Furthermore, due to the high monetary investment involved, it also has the potential to create differential vulnerabilities within the same settlement (ibid). Given their limited access to certain non-structural measures such as insurance or social security systems, households rely on diverse sources such as the government, NGOs, private institutions, and citizens for relief and support after flood events (Patankar & Patwardhan, 2016). However, this support is only for a short period, after which residents often have to depend on their own resources for long-term adaptation and loss reduction. Households that lack access to different social networks, such as family, local groups, and employee associations, are among the most vulnerable. Furthermore, access to different types of resources is significantly shaped by socio-economic and cultural factors.

Figure 10 Adaptation efforts at the household level (from left to right): Elevating furniture, raising the house level if affordable, covering the roof with tarpaulin sheets against heavy rainfall, Source: own

While the above measures are crucial in coping with flooding, long-term sustainable adaptation would call for addressing contested issues of affordable housing, rehabilitation and resettlement policies, land use planning, and land ownership. Slum rehabilitation and redevelopment has a long and controversial history in Mumbai. While policy measures such as the Slum Rehabilitation Authority scheme to provide free housing to slum dwellers were introduced, their effectiveness and success in providing safe and affordable housing have been critiqued (Anthony, 2022; Virani, 2022a). Moreover, the scheme has been questioned for being rather focused on profit-making for developers than people centric. This would, therefore require a shift in prioritizing human welfare in addition to

economic growth and development (Chatterjee, 2010b). A major project that the city will witness in this respect will be the redevelopment of Dharavi, one of the world's largest slums and home to almost 1 million residents and thousands of cottage industries. Located in central Mumbai, the redevelopment and resettlement of slum dwellers and their small-scale businesses will be a challenging task as gaining consensus will be difficult. This endeavour has been contracted to Asia's richest man, Gautam Adani, but with a stake of 20% held by the state (Lewis, 2024). Furthermore, studies have also pointed out an ignored yet urgent need to provide safe and affordable housing for the populations living in informal settlements or "encroachments" that are often blamed for causing flooding through obstructive settlements in flood plains, wetlands and along drainage channels (Bardhan et al., 2015; Jha, 2020; Sarkar & Bardhan, 2020). Adding to the already contentious issue of removal of "encroachments" for "reclaiming" flood plains, ecosystems, drainage basins is the dependence of the middle classes, different service sectors and other parts of the economy on the informal labour that resides in these settlements located in central areas of the city.

On the other end of the spectrum to the marginalized populations living in informal settlements are the elite of Mumbai who live in high-rise towers and sea-facing apartment buildings and in between are the middle-class sections of society. While they are also affected by flooding, the extent of the impact is significantly different from that of the informal settlements and slum dwellers. Impacts on the middle class and elite sections of society usually include inconveniences through damage to road infrastructure, disruption of public transport services, and mobility in general due to waterlogging. Being closely dependent on the informal sector, indirect impacts on the labour and services provided by them became visible in the migrant crisis during the pandemic when their absence was felt (as mentioned earlier in this section). However, while they are not heavily impacted, the middle class and elite play a role in shaping debates on flood risk management and urban development more broadly (Kundu, 2011; Parthasarathy, 2003). In some cases, for example through exclusionary civic policies, such as blaming "encroachments" for causing flooding and asking them to be removed, pushing for infrastructure projects that benefit the elite such as the Coastal Road (Mumbai Mirror, 2019; Parthasarathy, 2003).

Besides the formal, state-led measures for flood risk management and the individual, household or neighbourhood level initiatives and responses, there are several diverse actors and organizations who engage and play an important role in flood risk management in Mumbai – including civil society groups and organizations, academic institutions and experts, and private sector institutions. A formal mention of the inclusion of civil society in urban development and adaptation is stated in the National Action Alan on Climate Change (Government of India, 2008) as well as in the state-level 'Maharashtra State Adaptation Action Plan on Climate Change (MSAAPC) (TERI, 2014). Civil society organizations and nongovernmental organizations (NGOs) have played an important role in flood risk governance and management largely through advocacy for consideration of environmental risk and threats to human livelihoods and security in urban development, land-use planning, and implementation of large infrastructure projects (Jha, 2020; McFarlane, 2012; Zérah, 2008). A recent example of active civil society participation was the protests against the Coastal Road project – a 29.2 km eight-lane motorway that is expected to heavily impact coastal ecosystems and livelihoods of indigenous fishing communities living along the coast due to its design (Figure 11) (Movik et al., 2023; Singh et al., 2021). While the Coastal Road is primarily argued for reducing congestion and travel time (intended to benefit a minor share of the commuters who use cars), the road was also proposed to

function as a sea wall (Kirtane, 2019). Civil society groups have also been active at different scales – neighbourhood, wards, and at the city level. Many organizations such as Conservation Action Trust, Vanashakti, SPARC, and YUVA among others are also involved in the implementation of measures such as rainwater harvesting, beach clean-up, mangrove protection, community-led vulnerability assessments, youth development, access to civic services etc.

Figure 11 Coastal Road – construction work underway, Source: own

The advent of neoliberal policies marked an increased transfer of responsibility to civic society. According to the UFM guidelines, civil society is expected to play a stronger role not only in relief activities, but also in rehabilitation, reconstruction, and mitigation. The Disaster Management Act (GoI, 2005) further expects civil society to support the state in activities such as capacity building, training, and education in disaster response. The corresponding National Disaster Management Plan (NDMA 2010) also explicitly calls on civil society "to consider the enhancement of the socio-economic conditions of the poor, alleviate poverty and improvement of livelihood of these vulnerable groups" (GoI, 2010, p.102). Furthermore, in addition to formal support from civil society organizations, studies and media reports have also noted the importance of informal non-state actors or other types of civil society groups such as schools, local clubs, religious organizations, and community groups that mobilize and provide voluntary support during and after floods, often due to proximity to the flooded areas and the affected communities (Chatterjee, 2010a; Singh et al., 2021). While they are not formally recognized or registered as relief organizations, they play an important role in emergency relief when formal government support is delayed or difficult (Zimmermann et al., 2023). Another example of the role of informal non-state actors in the formal sector (to fill a vacuum unable to be provided by the state) is the integration of informal ragpickers in the formal waste management system in Mumbai led by civil society leaders in partnership with the municipal authority, supported by private sector funds (Boyd & Ghosh, 2013).

To conclude this chapter, it therefore argues that Mumbai provides not only an important but also highly relevant empirical case study in the debate on social contracts for adaptation. It exemplifies the need for explicit social contracts for adaptation as it brings together very heterogeneous groups with competing, often conflicting priorities and starkly different capacities. Mumbai also proves an apt unit of analysis at the intersection of the empirical and methodological contribution of this study in terms of the use of social listening through Twitter. India has the second-largest digital population with 692 million 'netizens' or internet users (Statista, 2024b) and the third-largest in terms of Twitter users (Statista, 2024c). Mumbai is under heavy pressure to adapt, being one of the major climate risk

and adaptation frontiers globally. However, it is also the financial capital of the fifth largest economy and largest workforce and has high adaptive capacity in principle. Yet it is confronted with several challenges shown in this chapter. Therefore, understanding which priorities different actors in Mumbai have and their expectations on roles and responsibilities are of pivotal importance for shaping coherent social contracts to achieve sustainable and equitable adaptation.

5. RESEARCH FINDINGS AND KEY PUBLICATIONS

This chapter outlines the key findings of this research, which have been published (including one under review, re-submitted after minor revisions) as scientific peer-reviewed journal articles (as shown in Table 1). Each article makes core contributions to the research questions through conceptual, empirical, and methodological means (Table 1).

In the first publication, the assessment of social contracts using an innovative approach, namely through social listening on Twitter is shown. The second article focuses on actor-specific multi-dimensional evaluations of perceived adaptation solution spaces in terms of desirability and feasibility criteria. The third study operationalizes social contracts for adaptation by looking at the adaptation objectives and roles and responsibilities associated with the solution space presented in the second publication. The chapter is structured in the following way. Each publication is briefly introduced by providing a concise summary of the objectives, methods, main findings, and key contributions to the dissertation. This is followed by the corresponding full version of the article. The synthesis of the findings and contributions from all three core publications comprising this cumulative thesis will be woven together in Chapter 6.

5.1 Using 'social listening' through Twitter to assess social contracts for adaptation

Citation

Doshi, D., & Garschagen, M. (2023). Assessing social contracts for urban adaptation through social listening on Twitter. *npj Urban Sustainability*, *3*(1), 30.

5.1.1 Summary

Introduction

The core motivation of this first empirical study was to explore a novel methodological approach – of 'social listening' to assess social contracts for adaptation. This article makes the most innovative contribution to this dissertation by expanding the methodological toolkit to assess social contracts for urban adaptation. This paper develops the main theoretical framework to argue that coherent social contracts in which different actors agree on a shared vision or goals and a clear distribution of roles and responsibilities to achieve them is a crucial requirement to foster sustainable adaptation to the unprecedented impacts expected from climate change. The center stage of this analysis (as well as in this dissertation on social contracts) is to address the urgent requirement of understanding 'imagined social contracts' on expected roles and responsibilities. Understanding what actors expect of each other is particularly important in the case of multi-actor constellations such as in cities where very diverse social groups come together. However, the empirical evidence for actors' expected roles and responsibilities is limited, as they are often tacit in nature and difficult to capture across large populations and heterogeneous societal groups.

Methodology

Adopting a grounded theory approach, the study combines big data (Twitter) and qualitative analysis methods to develop and apply a novel approach of 'social listening'. Social media (data) offer an important arena (and data source) to assess the exchange of opinions of different actors such as the state, citizens, civil society, private sector, etc., and examine their perceptions on adaptation roles and responsibilities they ascribe to other actors and themselves. Using the case study of Mumbai to prove the innovative potential of our approach for understanding social contracts for urban adaptation, I collected a dataset of ca. 70,000 Tweets comprising ca. 1.3 million auto-coded segments on flood risk management in Mumbai over four months of the monsoon season of 2021. The motivation for exploring big data potential for this paper was partly also borne out of the necessity to overcome the challenge of the COVID-19 pandemic-induced travel restrictions, which prevented me from going to the field (Mumbai) for over 18 months. While we drew on both quantitative and qualitative methods, the deeper knowledge gained was from the latter. The former helped to understand the profile of participants of the dominant debates on Twitter and trends in the major themes discussed. However, the in-depth qualitative analysis of the Tweets was insightful in understanding which adaptation roles and responsibilities were ascribed to different actors and the gaps between them through the nuanced sentiments expressed.

Findings

Overall, we found that in terms of the Twitter user profile, the majority (59%) of contributions came from accounts belonging to individuals/private users, who would most likely be residents or otherwise have a close connection to the city. This was followed by accounts from media outlets, civil society groups, public sector authorities (municipal bodies, state level departments etc.) and individual politicians and leaders of political parties etc., and private companies (mainly from weather forecasting, insurance, and aviation firms). Despite limited data on the demographic

characteristics of the users, we could identify the composition of users to be primarily belonging to the educated and affluent middle classes and elites, when measured along the Tweet's language (82% in English) and type of device (27% from Apple devices) used to post the Tweet. Even though the proportion of better-off and affluent users who, according to our data, contribute over-proportionally to the dominant debate, our qualitative analysis showed that many users, e.g. civil society groups and individuals, raised their concerns for others, especially marginalized groups. We found that the themes raised in the Twitter debate covered a wide range of topics, of which, however, a majority were relevant for a social contracts analysis, such as transport-related concerns, complaints, demands, etc.

Our results from the qualitative analysis of different actors' perceptions of expected roles and responsibilities showed wide gaps and contestations between not only different imagined social contracts but also between the imagined and practiced or the legal-institutional and imagined social contracts. For example, on the former, we found surprisingly stark contestations regarding the roles and responsibilities towards the poor and most vulnerable populations living in informal settlements in highly flood-prone areas. On the latter, we found, for instance, a large gap between the aspirational (what actors should do) and realistic levels (what actors will do) of expectations from the public sector. We additionally identified that expectations towards individuals to take responsibility were primarily self-ascribed, i.e. from individuals themselves. Expectations towards the media were mainly directed towards stopping "doom and gloom" stories about Mumbai and questioning the higher international coverage of floods in the US and Europe vis-à-vis Mumbai. Overall, the gaps identified provide important insights for adaptation governance by laying open and making explicit the often tacit and implicit expectations on roles and responsibilities different actors have.

In contrast to the oft-employed quantitative analyses of sentiments into positive, negative, and neutral, the qualitative analysis helped to capture nuanced expressions of actors' expectations and understand the resulting gaps in the different dimensions of social contracts – imagined, practiced, and legal-institutional. Sentiments such as frustration, anger, apathy, hope, sarcasm, etc. expressed in tweets proved particularly useful in identifying and understanding what these gaps are, where they might be, and how actors might deal with them.

Hence, this analysis makes three key contributions to the dissertation and wider debates on adaptation. First, it shows theoretically and empirically, that laying open and becoming aware of the gaps between different actors and dimensions (imagined, practiced, legal-institutional) of social contracts is a necessary first step towards closing them and forming coherent social contracts for adaptation. This highlights our hitherto very limited understanding – both theoretical and empirical – of imagined social contracts as well as their relation to the practiced and legal-institutional dimensions of social contracts. Our contribution by laying open the gaps and disagreements aims to inform a discussion to arrive at coherent social contracts – either one of an arrangement despite the differences in opinions or, ideally, one where actors negotiate to align their differences and close the gaps. Second, methodologically, it shows the value of using social listening as a novel approach for capturing unsolicited and unfiltered views in a large-N sample in almost real-time. It highlights the potential of further research in exploring this "digital town square"(Burgess, 2022). Finally, a novelty at the interface of conceptual and methodological contributions, the explicit analysis of sentiments proved very helpful in identifying tacit expectations where actors might not articulate them clearly or directly.

We suggest that such social listening approaches using Twitter or other platforms of active exchange can be of great relevance in dynamic high-risk contexts, in urban areas and beyond, especially with the likely expansion of internet access, social media users, AI tools, etc. Specifically, in societal contexts of multi-actor constellations that are confronted with heavy pressure to adapt and diverse competing or even conflicting perspectives yet lack a shared vision and agreed path to jointly move adaptation forward.

5.1.2 Article

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Assessing social contracts for urban adaptation through social listening on Twitter

Deepal Doshi[1] ✉ and Matthias Garschagen[1]

Adapting to climate change impacts requires a coherent social contract in which different actors agree on a clear distribution of roles and responsibilities. An urgent requirement is to understand the imagined social contracts on expected roles and responsibilities, which is particularly relevant in cities where very diverse social groups come together. However, there is limited empirical evidence on these expectations as they are often tacit and hard to capture across large populations and heterogeneous groups. Here we assess the social contract on flood risk management in Mumbai, using the concept of social listening in combination with Twitter data. We find wide gaps between and within imagined social contracts. Sentiments such as frustration and apathy expressed in tweets explain these gaps and highlight the need to build trust for achieving accepted and effective social contracts for adaptation. Theoretical, empirical, and methodological lessons can be transferred to other cities and beyond.

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INTRODUCTION

The impacts expected from climate change will be so pervasive, that they will require stepping up adaptation efforts significantly, in many respects requiring fundamental transformations in the way societies manage their risks[1–7]. Cities, in particular, are faced with high adaptation challenges given that they are often at the frontline of climate hazard exposure[8] whilst being characterized by high path-dependency, making transformative adaptation difficult and socially contested[3]. Meeting the stark adaptation challenges therefore will require collective efforts from different actors of society (state, citizens, civil society, private sector etc.), ideally with a shared understanding on common adaptation goals and clear distribution of tasks and responsibilities[9–13]. In reality, however, multi-actor constellations are often characterized by conflicting viewpoints on what actors expect from other actors or roles and responsibilities that actor groups ascribe to other actor groups. Related rifts and ambiguities have been identified as significant barrier in adaptation governance[14]. It is therefore important, first, to lay open and make explicit the often tacit or implicit viewpoints different actors have on their own as well as others' roles and responsibilities regarding climate change adaptation, second, to assess how actors in cities and other social contexts negotiate potentially diverging viewpoints and, third, to examine whether and how they settle at an arrangement which helps to moderate unresolvable gaps in expectations and ideally arrive at a shared vision on how responsibilities for adaptation should be distributed[15–21]. However, this understanding is largely lacking to date, especially in urban settings where diverse social groups and their worldviews clash.

Previous literature has made important contributions to assess how adaptation goals as well as roles and responsibilities for adaptation are being negotiated—which forms the core of adaptation governance[22]. The notion of 'social contracts' has in this context been suggested in the literature, arguing that such a lens can guide future research to explicate the complex politics of adaptation[23]. Yet, only a limited number of studies on adaptation and related fields of sustainability, resilience or disaster risk management have used the term social contract[9,13,17,21,24–26], and if so mostly in a loose and rather inexplicit or little conceptualized way. Most literature engages with topics around roles and responsibility for adaptation without explicitly referring to the notion of social contracts[10,14–16,18]. Also the latest IPCC assessment report, which is based on the available literature, does not explicitly assess social contracts for adaptation[22]. This shows that the concept has so far gained little traction, despite the presumed gains that it would hold for knowledge generation and decision support. Our study responds to the call for using social contracts as a stronger analytical lens[23] and develop an approach to empirically assess social contracts for adaptation.

Building on literature on adaptation goals, risk governance and responsibility for adaptation[9–13], we define a social contract for climate change adaptation as a collective arrangement between different actors of a society on the overall vision and goals as well as the mutual distribution of roles and responsibilities to achieve those goals. In other words, a social contract describes the collective arrangement of what a society wants and how it gets there. We conceptualize social contracts to be of two types (Fig. 1). Type 1 describes a social contract which exists where actors' visions and perceptions on mutual roles and responsibilities do not align but where actors seek a social contract to precisely mediate these differences. Type 2 describes a social contract in a situation in which actors' visions and perceptions on mutual roles and responsibilities align and actors seek a social contract to explicate and formalize this agreement.

Within each of these types (1 and 2), social contracts for adaptation can have three dimensions—imagined (ISC), practiced (PSC) and legal-institutional (LSC) (see Supplementary Table 1 for a detailed description)[23]. The ISC describes actors' envisioned goals and viewpoints on the distribution of roles and responsibilities. The PSC describes the 'real-life' goals and observable (de facto) distribution of roles and responsibilities for adaptation between actors. The LSC describes the formally defined goals and visions and legally encoded (de jure) distribution of roles and responsibilities for adaptation between actors.

Our center stage for the empirical analysis of this paper is on understanding the imagined social contracts (see Supplementary

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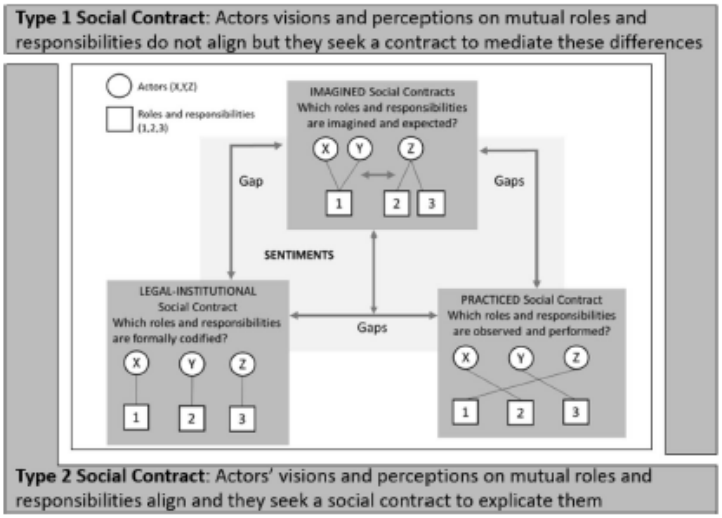

Fig. 1 Conceptual framework showing the types, dimensions, and gaps in social contracts.

Table 2 for detailed overview) and their relations to the practiced and legal social contracts. The imagined social contracts do not only result from the practiced and legal dimensions but also influence them. Hence, on the way towards encoding and practicing new social contracts, the most immediate need is a better understanding of the potentially diverging ways in which different actors envision new roles and responsibilities for other actors and themselves, i.e. which ISCs they have and wish for.

There may be gaps and contestations between the three dimensions of social contracts—for eg. rifts between the de facto, observable distribution of roles and responsibilities (practiced) and the de jure stipulations on formally defined roles and responsibilities (legal). Gaps could also exist within one dimension, e.g., when different actors have different imagined social contracts in mind regarding the distribution of roles and responsibilities. While it might not be possible to fully resolve these gaps and contestations, we suggest that engaging with these differences to at least identify them and become aware of them would allow actors to form a type 1 social contract to mediate the differences and deal with the gaps (which might still remain). Laying open these gaps and finding a way to deal with them would then ideally inform the process of actors aligning the gaps and potentially closing them with the objective of shaping a type 2 social contract.

Against this background, this paper aims to contribute to empirical knowledge on actors' perceived roles and responsibilities, the potential gaps and contestations between them and the ways in which they are currently being negotiated. By doing so, the paper aims to inform the discussion and formation of at least type 1 and ideally type 2 social contracts on climate change adaptation in cities and beyond.

The need for explicit social contracts for adaptation is most starkly illustrated in cities, proving a valuable and apt unit of analysis. Different viewpoints on adaptation goals and priorities often clash in cities, as it is there that very heterogeneous social groups – characterized by socio-cultural diversity, competing economic and political priorities, asymmetric power relations, different levels of risk tolerance and adaptive capacities—are coming together[27]. These gaps and contestations may arise in view of addressing pertinent questions on political feasibility, power dynamics and trade-offs involved, such as whose priorities get embedded in adaptation pathways, who decides whose futures are protected and how costs are distributed, which spatio-temporal trade-offs will need to be made etc[28].

We use the case study of flood risk management in the coastal megacity of Mumbai to assess the negotiation of social contracts for adaptation. Mumbai is the seventh largest metropolitan city globally and ranks among the top 10 coastal megacities at risk to coastal flooding and climate change impacts[29,30] and hence is characterized by some of the highest adaptation pressure one can find[31–35]. While the city witnessed its most catastrophic flood event in 2005, when one-third of its annual rainfall fell in 24 hours resulting in the death of 1493 people and estimated losses of USD 1.7 billion[36,37], heavy rainfall and flooding are almost an annual phenomenon during the monsoon season.

The current social contract for flood risk management in Mumbai is contested and riven between the practiced and legal social contract. Mumbai is confronted with stark inequality—being home to a powerful urban elite while 42% of the city's population lives in informal settlements. The latter are at high-risk to flooding. Informal settlers are often being forced to live in environmentally risk prone areas, are socially excluded from civic services and poorer[38], yet are often seen as illegal encroachments[39]. According to core national legislation[40], disaster management responsibilities are entrusted to the state. Previous studies point out two major shortcomings in the legislation: one, the silence of the Act on state responsibility towards those impacted by disasters[41] and two, the de facto implication of the Act on 'active and willing support and cooperation of the local community' in disaster management[42]. While the local municipal authority is entrusted with emergency response function, the national guidelines on urban flood management (UFM) foresee the role of citizens as first responders, even before state machinery steps in[43].

The UFM guidelines recognize that the role of civil society has shifted from being "mere relief organizations to focusing on rehabilitation, reconstruction and mitigation" (p.101). Civil society is further explicitly expected to play a role in reducing socio-economic vulnerability of the poor[43]. Previous studies have emphasized the de facto role of civil society organizations in coping with flooding in Mumbai[44,45]. However, against the context of India's economic liberalization which led to increased social and economic marginalization in major Indian cities, including Mumbai, it is important to note the dominant discourse on 'civil society' by urban elites which supports exclusionary restructuring

policies against the poor[39]. A recent example of elite capture is seen in the contestations around the highly controversial Coastal Road infrastructure project which is perceived to serve the elite and has prevailed despite protests against it due to its adverse impacts on the sensitive coastline, livelihoods of fishing communities and being labeled maladaptive[46].

Hence, there is an urgent need to capture the imagined, diverging viewpoints of different actors against this contested background. Furthermore, despite the freedom of speech being a constitutional right in India[47], declining press freedom has been a concern raised in national and international media citing corporatisation in ownership, political control, safety of journalists and absence of civil society demands as the main reasons[48,49]. Therefore, in this analysis we explore social listening on Twitter, as it forms an increasingly important marketplace to capture different opinions and voices. However, in the context of debates on flood risk in Mumbai, elite actors potentially play a significant role due to favorable factors such as digital access and literacy.

In the age of digitalization and big data, social media, in terms of its volume, scale and speed offers many opportunities for urban sustainability research as well as urban planning and decision-making[50]. A wide range of quantitative (descriptive statistics such as correlation, regression, cluster analysis etc.) and qualitative (content analysis, social network analysis, thematic analysis etc.) research methods can be applied to different types of big data including Twitter[51–54]. Examples of studies using geotagged Twitter data, or sentiment analyses in urban, sustainability and adaptation research is manifold[51,55–58].

Social media offer an important arena to inductively capture and assess the exchange of opinions and negotiations of roles and responsibilities of different actors such as public sector, citizens, civil society and private sector, including nuanced sentiments such as frustrations, hopes etc. Adopting a grounded theory approach[59], we combine the inductive exploration of data to capture the dominant debate on Twitter with a deductive application of a social contract theoretical lens. For this article, we developed and utilized the approach of social listening (also called social media analytics)[60], defined as an "active process of attending to, observing, interpreting, and responding to a variety of stimuli through mediated, electronic, and social channels"[61]. Hence, the analysis strikes a balance in combining the potential of big data with context-specific insights to capture "contextual complexity" in adaptation research—as called for by Ford et al.[62]. Fig. 2 summarizes our workflow, a detailed methodology description is provided in the Methods section.

RESULTS

Voices demanding better flood risk management and adaptation

In terms of the overall Twitter user profile, our data shows that the vast majority of contributions to the flood-related debate in Mumbai comes from accounts held by private users / individuals (59%), most of which are likely to be residents of the city or otherwise closely connected to it, followed by accounts held by media organizations (25%), civil society groups, public sector organizations and politicians (e.g., civic authority, political parties, politicians such as ministers or mayors) and private sector (mainly private weather forecasting, insurance and aviation companies) (Fig. 3). The smaller number of tweets by actors such as civil society or public sector does not necessarily translate into a minor contribution to and influence over the debate, as many of these actors effectively serve as multipliers, e.g., in the case of political parties or civil society interest groups.

The participants of the dominant Twitter debate are largely composed of educated and affluent urban middle classes and elites, when measured along the Tweet's language and type of device (Fig. 3). In India, the ability to communicate in English is strongly correlated with having a higher education level and economic status[63]. 82% of the tweets were posted in English, which compares to only 10% of the Indian population who speaks English. Even though the percentage of English-speakers is probably significantly higher in Mumbai—detailed numbers are lacking–this divide clearly indicates a dominance of the elite in the debate.

The picture that better-off actors participate over-proportionally in the flood-related Twitter debate also holds when looking at the type of devices used for tweeting (Fig. 3). 27% of the tweets in our dataset were posted from Apple devices, which compares to an India-wide market share of just above 3 percent for these devices[64] even though the market share is probably higher in the city of Mumbai. Also, 38% of tweets were posted from usually more affordable Android devices, which compares to a national market share of almost 96% for these devices (ibid). Even though these figures suggest that better-off and affluent citizens contribute to the Twitter debate over-proportionally, it is important to highlight that many Twitter users raised their voice for others. Our data hence shows that especially marginalized and highly vulnerable groups who are not directly participating in the debate on Twitter are still strongly represented e.g., by civil society organizations.

In terms of themes covered, our data shows that the Twitter debate covered a surprisingly wide range of topics, of which two-thirds of the tweets are in one or the other way relevant for the social contract analysis. Actors expressed their expectations of roles and responsibilities for flood risk management across a wide range of themes including transport-related concerns, complaints, impacts, demands etc. (Fig. 4b). One-third of the tweets mainly provided weather and waterlogging updates which provide relevant insights for flood hotspots mapping, early warning and emergency preparedness.

Roles and responsibilities ascribed to the public sector

Expectations towards the public sector and politicians, in particular the ruling party and state bureaucracy, were mainly raised by individuals and the public sector itself i.e. opposition parties. Not surprisingly, our findings show those voices would aspirationally expect the public sector, especially the drainage department of the city's civic authority, to be responsible for flood risk management. However, at the same time, our data clearly shows that in terms of realistic expectations—i.e. what the public sector will do rather than what it should do–actors did not anticipate the public sector and politicians to play that role in flood risk management. The analysis of sentiments proved to be an important lens for unpacking and understanding these gaps in actors' expectations in more detail.

First, we find an important gap between the imagined and legal-institutional social contracts which help us understand why individuals and opposition parties ideally expect that flood risk management should be a public sector responsibility. We identified two major sentiments—frustration and humiliation—that explained this gap. Out of frustration, individuals and opposition parties claim accountability for the allocation of taxpayers' money (Table 1, #1). Some voices even suggested to not pay taxes to the civic authority until the "waterlogging problem is solved" (Table 1, #2). This claim is also made in view of the allegations of corruption in drainage cleaning (legally a core task of the public sector[43,65]), as reported by mainstream media in the past years[66–68]. In addition, individuals expressed their humiliation when calling for public sector actors to take their responsibility for flood risk management more seriously. Tweets expressed feelings of shame, arguing that the city is facing flooding every year despite being the financial and commercial capital of the country and having the largest civic budget (Table 1,

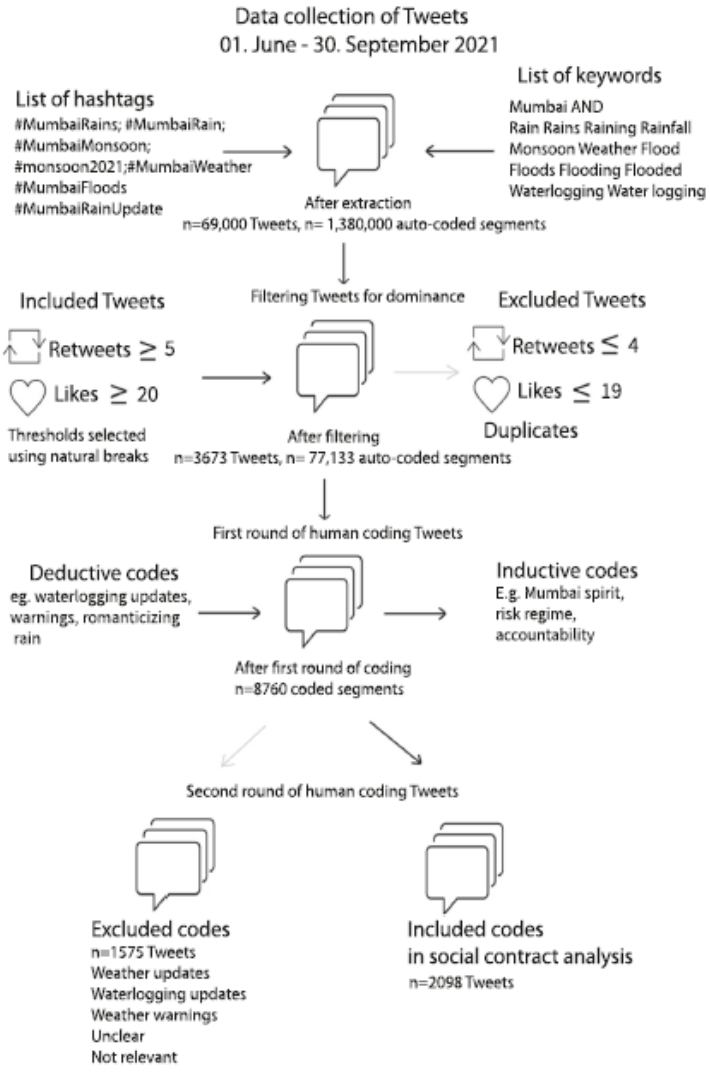

Fig. 2 Flowchart of steps undertaken in Twitter data collection and analysis.

#3). However, surprisingly, none of the tweets called for specific adaptation or flood risk management measures. Instead, tweets tended to be more generic and called on the public sector and politicians to find solutions to "fix" the flooding problem (Table 1, #4).

Second, we clearly find a gap between the imagined and practiced social contracts which help us understand why individuals and opposition parties did not expect the public sector and politicians to play a role in flood risk management in reality. We identified two major sentiments—the lack of hope but also sympathy—that explained this gap. Individuals expressed their lack of hope in two ways: First, individuals and opposition parties showed their disappointment and frustration when the public sector and politicians do not deliver on their promises made before the monsoon. Individuals and opposition parties argue that apathy and ignorance on the part of the public sector and politicians in power explain this pattern. Second, many actors have given up hope because of experiencing flooding year after year. Individuals in particular felt being taken advantage of for their 'everything goes' attitude and the infamous 'Mumbai spirit' (which is used to praise the resilience of Mumbaikars)[69] as an excuse by the public sector for their incompetence and poor governance (Table 1, #5, #6). Surprisingly, we identified a mix of humor and sarcasm to be a crucial sentiment in expressing and dealing with these gaps. Diverging from this view were a limited number of tweets, however, which also expressed sympathy for the public sector due to the intensity of rainfall.

Third, and probably most importantly, tweets revealed major contestations and gaps in the way different actors or even members of the same actor group (e.g., individuals) perceive and envision the imagined roles and responsibilities (ISCs) of public sector actors. These contestations most clearly surfaced in relation

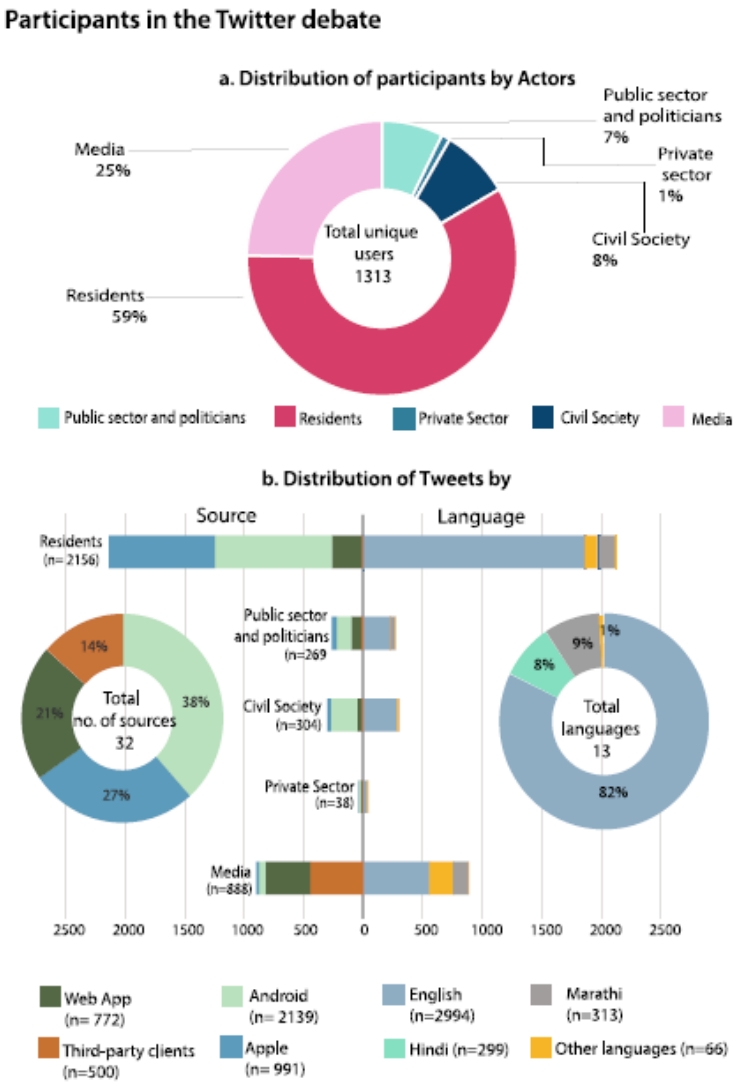

Fig. 3 Profile of participants in the Twitter debate. a Distribution of Twitter users by actors; **b** Distribution of tweets by source device and language.

to the – often very laden – viewpoints on how to deal with the most vulnerable who often live in informal housing in high-risk areas. This debate peaked after thunderstorms and heavy rainfall led to landslides and collapsed walls, causing deaths of more than 30 people in mid-July 2021[70], six weeks into the data collection (Fig. 4). In favor of the vulnerable, individuals, civil society, other political parties and politicians expressed sorrow and sympathy. Public sector actors responded to the incident by expressing condolences and announcing relief and compensation. Individuals and civil society expressed their anger and demanded (including a petition to the High Court) to relocate the most vulnerable to safer areas because they did not accept the status quo (Table 1, #7). Many individuals asked who was responsible for "this mess", "these deaths", "fallen houses, buried people, sunken cars" and "why was nothing done to evacuate people from low-lying areas". In contrast, other individuals blamed the flood victims and demanded to remove them, arguing that they are illegal dwellers and taxpayers' money should not be used for their rehabilitation. Supporting arguments to this narrative believed that such settlements were being protected by politicians due to their important role as vote banks, in line with other studies[38]. The High Court dismissed the petition for basic survival support for the homeless coping with lockdown, saying "homeless must work, not expect everything for free" as also reported in the media[71,72] (Table 1, #8).

Roles and responsibilities ascribed to individuals

Expectations towards individuals were primarily from individuals themselves and to a small extent from the public sector. Two

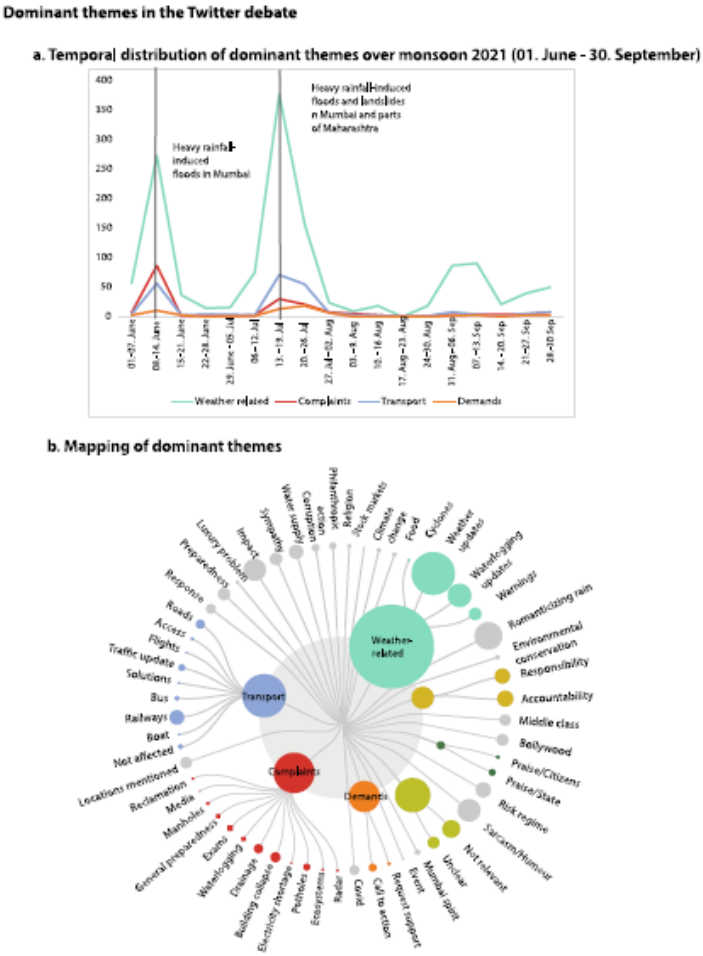

Fig. 4 Dominant themes and trends in the Twitter debate on flood risk management in Mumbai. a Temporal distribution of dominant themes in the Twitter debate over monsoon 2021 (**b**) Mapping of dominant themes in the Twitter debate.

diverging views could be identified. On the one hand, individuals questioned the responsibility of individuals and called out especially to the middle classes and the 'dominant castes and classes' to participate in politics and exercise their voting rights if they are not satisfied with the current leadership's performance of flood management (Table 1, #9). Some individuals blamed other citizens of Mumbai for their ignorance and apathy under the disguise of 'Mumbai spirit' and humiliated fellow individuals for "watching this process for 25 years" for which they should be ashamed of. Similarly, some individuals questioned their impatience and lack of outrage given the high flood impacts and even casualties (Table 1, #10, #11). They perceived this as giving in to the alleged corruption by the public sector, arguing that corruption is one of the main culprits of ineffective drainage cleaning. Overall, many individuals blamed their fellow individuals to lack agency in the fight against the flood problem. Yet, others maintained that in times of "bad consequences" such as the "Mumbai rain", it is the "people around you" that "come to help, not the politicians for whom you fight on social media everyday", indicating many individuals already were active in self-help and others should become more active in that respect.

On the other hand, other individuals also asked fellow Mumbaikars to stop complaining about the floods in Mumbai. For example, media coverage of floods in the US and Europe at the same time as floods in Mumbai[73–75] triggered some individuals to argue that Mumbaikars should not complain if even the developed world can be impacted by floods in such a drastic manner. Sympathizing with the public sector, some individuals believed that people should not be too critical of the public sector due to the intensity of rainfall. One view even asked all people who have a problem with "# MumbaiRains" to "quit the city" (Table 1, #12).

We identified only one major expectation from a politician to individuals, calling for the "rich and elite" to step forward and contribute to relief and support measures following the floods in Mumbai and parts of Maharashtra[76]. Other political parties expected individuals to be alert to "who really cares for them, who can solve their problems".

Table 1. Example of Tweets supporting main findings

Roles and responsibilities		Tweet	Retweets	Likes
Roles and responsibilities ascribed to public sector and politicians	#1	Translated: In this city, one will find pits and holes, But even if you look, would not find the culprit #MumbaiRains #Monsoon2021 #Mumbai https://t.co/zlrunfCwmR	1256	10899
	#2	I personally feel, people of Mumbai shouldn't pay taxes till every year's rain water logging is sorted... Every year, same sight and no action to handle the situation for next year.. #Mumbai #MumbaiRainUpdate #MumbaiMonsoon	45	222
	#3	This won't change. Now the incompetent politicians are blaming heavy Rainfall.what a shame. Is this the first tym this is happening? What happened to all the taxes collected by rich BMC? No solution all these years No solution for encroachments? #MumbaiRainUpdate #Chembur https://t.co/zJS3W6YslW	32	152
	#4	For decades, @mybmc has been unable to fix the flooding at King's Circle, Matunga. See the situation today. And we are the richest civic body in the entire country. Vote these haftawallahs out in 2022. #MumbaiRains https://t.co/6SUs8zelRa	61	290
	#5	Everything is covered in the name of Mumbai's spirit during Mumbai Monsoons. It's the survival and being left on your own. #MumbaiRainUpdate	28	250
	#6	"Lets hide every failure of BMC under the name of Mumbai Spirit https://t.co/N9x6BrmiIw #MumbaiRainUpdate".	35	118
	#7	Saddening that over 25 people died due to wall collapses in Chembur &Vikhroli What is not acceptable is,if @OfficeofUT saw this coming,why was nothing done to evacuate people from low lying areas? #BMC,has been ruled by #ShivSena for 35+ yrs&yet this apathy? #MumbaiRainUpdate https://t.co/AEWXO4xhm9	121	411
	#8	Petition for basic survival support for homeless people coping with lockdown such as nutrition food & clean water. Dismissed by Mumbai High Court, saying homeless must work, not expect everything free. Extreme insensitivity: the homeless work very hard, else they wouldn't survive https://t.co/8LJy62Qok	29	77
Roles and responsibilities ascribed to Residents	#9	"Mumbai's middle class summed up: "As long as there are no potholes, no water and electricity cuts, Ola, Uber and Swiggys, and the trains run on time, why should we middle class people get involved in politics? Just work for some years and try and get US, UK or Aussie Citizenship"	36	128
	#10	"Mumbaikars will post about #MumbaiRains & related issues 30 times a year but won't go out once in 5 years to vote out the corrupt nexus that has ruled Mumbai for 30 years. The Mumbai Spirit."	433	1929
	#11	I think the so called Mumbai Spirit has made us insensitive. Immaterial what happens we have to keep working as if nothing happened. More than 20 ppl lost there lives in Mumbai due to rains & most are poor citizens. So obviously no outrage."	45	152
	#12	To everyone who have problems with #MumbaiRains and pleading to stop every time it pours, fuck off and quit the city. I know cleanliness and flooding is a problem but the city is dependent on rains even for drinking water. So let it pour please.	10	61
Roles and responsibilities ascribed to Media	#13	Mumbai floods don't make international news, but they still wreck lives. Like all climate disasters they will continue to get rapidly worse unless we stop adding greenhouse gases to the air. https://t.co/xCj7Ik5GoK	108	223

Role and responsibilities ascribed to the media

Individuals mainly expressed disappointment with the media and called for a stop to "doom and gloom" stories about Mumbai especially in view of the floods affecting the US and Europe as well. They also perceived international media as biased towards covering flood impacts of the US and Europe in comparison to "Mumbai floods" which "don't make international news but still wreck lives" (Table 1, #13). This led individuals to believe that "some lives are more valuable" and question "why so many people in the US and Europe don't care about the rest of the world".

Gaps hindering a new social contract for flood risk reduction

Overall, our results show that there are gaps in the social contract on flood risk management in Mumbai on two levels: first, between different social contracts such as the practiced and imagined or the legal-institutional and imagined and, second, between different imagined social contracts. On the first, we found a large gap between the aspirational (what actors should do or want them to do) and realistic (what they believed actors would actually do) levels of expectations towards the public sector. On the second, we found surprisingly stark contestations regarding the roles and responsibilities towards the poor and most vulnerable

populations living in informal and highly flood-prone settlements. We also found similar gaps in expectations within the same actor group in other respects, most notably the levels of agency that individuals expect of fellow individuals.

Hence, our results show that there are not only wide gaps between the current de facto flood risk practices, the legal de jure stipulations and the envisioned flood risk management, but also between the social contracts imagined for the future, even within allegedly joint actor groups. These gaps are troubling in view of the already grave and intensifying flood problem, the heavy financial and human-resource costs of adaptation and the urgency resulting from long lead times of adaptation policies and actions. The results suggest that laying open these gaps is a necessary first step towards closing them and building a future social contract which helps mediate these differences and maybe/ideally form a coherent joint perspective.

DISCUSSION

We started our analysis by arguing that adapting cities to the inevitable impacts of climate change will require a strong and ideally coherent social contract in which different actors share an overall vision and agree on a clear distribution of roles and responsibilities for achieving that vision, despite potential differences in their respective individual perspectives. Our findings highlight the importance of improving our hitherto very patchy theoretical and empirical understanding of imagined social contracts in particular—and their relation to practiced and legal social contracts.

We found that there can be surprisingly large contestations and wide gaps regarding the roles and responsibilities which different actors envisioned for and ascribed to other actors. Our contribution is to lay open these gaps and disagreements in order to inform the discussion for actors to find an arrangement despite differences in viewpoints and arrive at a type 1 social contract. Ideally, we hope to even inform the process for actors to align the gaps and contestations—forming a type 2 social contract. Hence, through social listening, our findings show that becoming aware of these gaps between different expectations and decoding their drivers is the first step towards building new and coherent social contracts, so urgently needed for effective and equitable climate change adaptation across the globe[77].

A social listening approach allowed us to capture unsolicited and therefore open views in a large-N sample and almost in real-time. Twitter is an increasingly important digital marketplace to negotiate and express opinions between different actors and hence, an important empirical database for analyzing evolving social contracts. The explicit analysis of sentiments expressed on Twitter turned out to be a useful tool which helped us to understand and explain the reasons driving disagreement on perceived roles and responsibilities between different actors. Combining big data approaches with manual qualitative coding allowed us to identify more nuanced sentiments such as apathy or frustration as compared to an algorithm trained classification of sentiments as positive, negative and neutral. This proved particularly helpful where expectations are tacit, i.e. where actors do not articulate them clearly and directly. Overall, the identified sentiments indicate a lack of trust between different actors and we suggest they might provide a helpful entry point into studying the formation of social contracts in other contexts or countries.

Despite the burgeoning potential of using social media data, a major limitation for this analysis is the representation of populations. Participation on social media is inherently linked to internet access and varies across geographies and demographics—also known as the "digital divide"[78]. Social media platforms including Twitter essentially allow to capture debates across trans-local networks, hence, the demographic composition of the actors in the Twitter debate in comparison to the demographic composition of the geographical population of Mumbai is not inherently problematic in our analysis. However, in the context of Twitter debates on flooding in Mumbai it may be important to bear in mind that urban elite are more likely to participate (in view of the dynamics discussed above) in comparison to informal, vulnerable populations. Nevertheless, civil society organizations, media, academics etc. still represent the concerns of the vulnerable populations.

In this study we do not aim to provide a complete assessment of social contracts in Mumbai through social listening, but capture an important segment of that debate taking place in the upcoming virtual space of Twitter. It is certainly not the only channel of information to understand the negotiation of social contracts and needs to be triangulated with other lines of information such as formal participation processes, informal discussions in local neighborhood groups etc. However, the importance of social media platforms is growing, especially with a growing middle class and India having the third largest Twitter community globally with its 23.6 million active users, preceded only by the USA and Japan[64]—making it a crucial case in Twitter research.

Social listening offers an important arena to capture dynamics of social contracts at unprecedented speed and scales, ranging from locally urban to global scales. Given the trans-local nature of social media debates, the approach used in this study could also be applied in other countries, albeit in view of the limitations and country context. For future research, we suggest, that using Twitter or other platforms of active exchange can be of great relevance in laying open gaps in high-risk contexts, including urban areas, in which different actors are faced with a high adaptation pressure and diverse competing, or even conflicting, perspectives but currently lack a clear and agreed strategy or even vision to jointly move adaptation forward[50,52,79].

METHODS

Data collection

In order to understand the imagined social contracts by different actors in Mumbai, we captured all flood risk related tweets over the monsoon season of 2021 (~70,000 tweets with 20 variables of metadata such as the author's Twitter handle, number of re-tweets and likes, URL of the author etc. for each Tweet resulting in 1.3 million values of metadata). In a nutshell, we collected data through specific hashtag and keyword combinations and then filtered the results for dominance, with ~3600 dominant tweets defined through a high level of engagement in terms of re-tweets and likes. We then manually coded the tweets in order to show which actors participated and the major themes that emerged in the dominant debate on flood risk management. Subsequently, we filtered roughly two-thirds of the codes most relevant for the social contract analysis and coded and analyzed these tweets even more comprehensively (e.g., for underlying sentiments). In contrast to most studies which conduct quantitative sentiment analyses using Natural Language Processing (NLP) or other machine learning methods, we manually code sentiments to capture important nuances in the tweets (often multi-language tweets, context-specific words, memes and sentiments such as humor and sarcasm) to go beyond the positive, negative and neutral classifications generated by algorithms. We defined sentiments as feelings or emotions associated with viewpoints or opinions shared in a Tweet.

In a first step, we screened tweets on flooding in Mumbai in order to develop a list of the most popular hashtags and key-word combinations to capture the Twitter debate on flood risk in Mumbai. This list was revised in the first four weeks of data collection wherein hashtags which did not receive any hits were deleted and some new ones which gained popularity were added.

Table 2. Auto-coded metadata variables extracted for each Tweet using the Twitter API on MaxQDA.

	Auto-coded metadata by Twitter API in MaxQDA	Example	Use in the analysis
1	Date and Time	26.07.2021 15:03:36	Timeline analysis of tweets
2	Tweet	Maharashtra floods: Mumbai has some of richest people in world, they should help, says Sanjay Raut | Mumbai News—Times of India https://t.co/R8kMjbc0GE	Qualitative analysis for theme and sentiment
3	Hashtags	-	
4	Type	Tweet	Analysis focused on tweets, not re-tweets and replies
5	Answer to	-	
6	Author	rautsanjay61	Used to determine 'Actor' type in the dominant debate
7	Real name of author	Sanjay Raut	
8	Author place	Mumbai, India	
9	Author time zone	-	
10	Author URL	https://t.co/RHtudzxG0u	
11	Author description	Executive Editor, Dainik Saamana. Member of Parliament, Rajya Sabha. Shiv Sena Leader.	
12	Followers	835095	
13	Following	261	
14	Tweets	1891	
15	Profile verified	True	
16	Profile created	13.12.2013 15:28:05	
17	Retweets	290	Threshold of 5 and more for filtering dominant debate
18	Likes	2397	Threshold of 20 and more for dominant debate
19	Language	English	Proxy indicator for socio-economic status of user
20	Source	Twitter for Android	
21	Tweet coordinates	-	

The final list included: #MumbaiRains, #MumbaiRain, #Mumbai-Monsoon, #monsoon2021 AND Mumbai, #MumbaiWeather, #MumbaiFloods, #MumbaiRainUpdate, one of the words (Rain Rains Raining Rainfall Monsoon Weather Flood Floods Flooding Flooded Waterlogging Waterlogging) AND Mumbai. Tweets were extracted using the Twitter API of MAXQDA. The results of the tweets extracted from MAXQDA's Twitter API were compared to tweets extracted using Twitter's Academic access API through R. Given no difference in the tweets, MAXQDA's Twitter API was continued as it would allow easier synchronization for qualitative coding in future steps of the analysis.

Tweets were collected for a period of 4 months from 01 June to 30 September 2021—corresponding to the monsoon season in Mumbai. The monsoon season of 2021 was preceded by Cyclone Tauktae in May and India's worst Covid-19 wave of the Delta variant from March to May. During the monsoon months of 2021 there were two major flood events in Mumbai and in other parts of Maharashtra. The floods in Mumbai also coincided with floods in Europe and in USA. The debates on Twitter are generally very open, in line with the long tradition of the country's free speech and backed by The Indian Constitution which guarantees all citizens the fundamental right of "Freedom of speech and expression" in Article 19[47].

A total of ca. 69,000 Tweets with around 1.3 million auto-coded segments were collected over these 4 months. Each Tweet text extracted using the MaxQDA API comes with 20 variables of metadata for example "Date and Time" when the Tweet was posted, "Author" name of the user on Twitter, "Author description" which is the self-description of the user on Twitter etc. Table 2 below shows the auto-codes during data extraction and how they were used in the analysis.

Data filtering and coding

Tweets were filtered for capturing the dominant debate. Dominance was operationalized in terms of level of engagement (re-tweets and likes). Based on natural breaks in the data, the threshold for dominance was set at 20 likes AND 5 re-tweets to qualify as a "highly dominant Tweet". Hence, the dominant debate comprised of tweets that fulfilled both criteria since re-tweets and likes also showed a strong positive correlation. After filtering for dominance and removal of duplicates, the first database for manual coding comprised of 3673 tweets with 77,133 auto-coded segments.

The first round of coding generated 8760 coded segments with 29 primary-level codes and 33 secondary level codes. We found that two-thirds of the dominant debate (2098 tweets) comprised of primary-level codes such as transport, complaints, impacts, accountability etc. which are relevant for the social contract focus of the analysis in this paper. One-third of the debate (1575 tweets) were on weather related updates such as waterlogging, warnings etc. providing valuable information on flood hotspots and early warning communication. In a second round of coding tweets were further clustered according to roles and responsibilities ascribed to different actors: the public sector and politicians, individuals and media. A qualitative codebook is provided in Supplementary Table 3.

DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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AUTHOR CONTRIBUTIONS

D.D. and M.G. conceived and designed the experiments; D.D. and M.G. performed the experiments; D.D. analyzed the data; D.D. and M.G. contributed materials/analysis tools; D.D. and M.G. wrote the paper.

COMPETING INTERESTS

The authors declare no competing interests

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5.1.3 Transition to the second paper

The first study established the guiding conceptual framework and developed an approach of using social listening through Twitter to assess social contracts for adaptation. The empirical findings, drawing on a large N data sample of Tweets, showed wide gaps and contestations on adaptation roles and responsibilities that actors ascribed to each other for flood risk management in Mumbai. While the first paper establishes the importance of assessing social contracts for adaptation through an innovative method, a crucial step on the way toward achieving coherent social contracts is the need to understand actors' perceived solution spaces and how they evaluate different adaptation options. Building on the key findings of the previous analysis, the second paper delves deeper into the case study of Mumbai and draws on semi-structured expert interviews, aiming to understand how different stakeholders evaluate various adaptation measures in terms of feasibility and desirability criteria.

5.2 Advancing multi-dimensional evaluations of perceived solution spaces for adaptation

Citation

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5.2.1 Summary

Introduction

Adaptation to the increasing impacts of climate change will require societies to design portfolios of different risk management solutions by selecting from an array of available adaptation options, as there is no "one-size-fits-all" approach for adaptation. There is a need to understand how actors evaluate adaptation options beyond traditional binary assessments and cost-benefit analyses. Progress has been made in assessing the strengths and weaknesses of different adaptation options, such as the multi-dimensional feasibility assessment applied in the IPCC's Special Report 1.5 (IPCC, 2018b) and the latest sixth Assessment Report (IPCC, 2022b). Yet, it has not focused on two questions – first, how different actors perceive and evaluate different adaptation measures, and second, going beyond the current barrier-oriented approach, how different dimensions might play not only a constraining but also an enabling role. Finally, another shortcoming of current approaches is that they lump desirability into feasibility assessments. It is increasingly clear that actors often perceive and evaluate the desirability (what they want or should be done) and feasibility (what is possible or could be done) of adaptation options differently, therefore warranting an explicit and distinct analysis of both.

In this regard, this study makes an important step in going beyond current multi-criteria evaluations of adaptation options in the following ways: first, it uses an actor-oriented multi-dimensional framework to understand who identifies which adaptation options and how they evaluate their perceived adaptation solution space. Solution spaces are "socially constructed" and influenced by actors' norms, values, priorities, etc. (Haasnoot et al., 2020). Hence, understanding actor-specific views becomes important to inform negotiations between potentially diverse/diverging perspectives. This could involve making trade-offs or difficult decisions in prioritizing different

options. Second, the study goes beyond current feasibility assessments that adopt a barriers approach and looks at how individual dimensions might play not only a constraining but also an enabling role in the evaluation of different adaptation options. This might be an important consideration in expanding the boundaries of the adaptation solution space. Finally, it separates desirability from feasibility in the actors' multi-dimensional evaluation of different adaptation options that make up the perceived solution space.

Methodology

We develop and apply the framework, built on the IPCC's feasibility assessment, to the case study of Mumbai. The analysis draws primarily on qualitative data collected through 37 semi-structured interviews with key informants across different actors such as the state (n=11), civil society organizations (n=12), and academic experts (n=14) working in the field of flood risk management in Mumbai. The data collection for the second (and third paper), carried out in 2021 and 2022, was possible largely because of timely access to vaccinations and my citizenship, which granted me visa-free travel to Mumbai. Despite the small N sample, it was possible to gain rich qualitative insights, in some cases even from important decision-makers in the municipal authorities who are often difficult to access. Adopting a grounded theory approach, an in-depth qualitative content analysis of the transcribed interviews was performed using MAXQDA, a qualitative data analysis software.

Findings

In total, the analysis yielded the following five key findings. First, among all identified adaptation options, actors expressed the largest priority for institutional changes. This was most emphasized in the portfolios of civil society and academic actors and also included measures for more fundamental shifts in the approach to flood risk management in Mumbai through overhauls of entire departments, for example. Second, the clearest consensus on desirability between the different actors was seen for nature-based options, although it quantitatively only made up a small share of the overall perceived solution space and appeared to be constrained by institutional and economic dimensions. Third, on the contrary, there was a stark divide between mostly state and non-state actors on the desirability and feasibility of physical infrastructure measures. Critical voices from civil society and academia highlighted the potential maladaptive effects and ineffectiveness of such measures, in line with current scientific debates. This is an important finding against the background of formal state-led flood risk management being dominated by physical infrastructure measures. Fourth, we find that actors emphasize the pivotal role of institutional dimensions in the multi-dimensional feasibility evaluation of adaptation options. This finding confirms the importance of institutional aspects for fundamental transformative adaptation discussed in the literature. Finally, we noted that the picture is not as clear in terms of the other dimensions and how actors consider them in the evaluation.

This analysis makes a conceptual and empirical contribution to this dissertation and further advances the scientific debate on the multi-dimensional evaluation of adaptation options by including actor-specific views and how they evaluate options in real-world settings. Hence, we argue that actor-specific evaluations of perceived adaptation solution spaces lay open subjective perspectives on the desirability and feasibility of different options, potential synergies, and contestations. These insights hold a strong potential to improve scientific evaluations of adaptation options, increase the practical usefulness of such assessments, and ultimately inform actors' discussions toward forming coherent social contracts for adaptation.

5.2.2 Article

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Ruptures in perceived solution spaces for adaptation to flood risk: Heuristic insights from Mumbai and general lessons

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ABSTRACT

Adaptation to increasing impacts of climate change will require societies to design portfolios of risk management solutions by selecting from an array of available adaptation options. A major step on the way towards a strong social contract for adaptation is understanding how different actors view different adaptation options. Here we adopt an actor-oriented multi-dimensional framework to understand how different actors evaluate their perceived adaptation solution space. The aim is to understand who identifies which adaptation options and how they are assessed. We build on the feasibility assessment used in IPCC's sixth assessment report and explore the framework by applying it to the solution space for flood risk in Mumbai. We draw on empirical data collected through key informant interviews with state, civil society and academic actors. Our findings show that, overall, actors see most need for adaptation measures in relation to institutional changes, e.g. in relation to planning procedures and a shift in risk management paradigms. While actors show consensus on the importance of green infrastructure, we find stark differences in their perception of grey infrastructure measures. In terms of the factors perceived to enable or constrain adaptation, actors agree on the pivotal role of institutional aspects as even more important than financial or technical factors. This study makes an empirical and analytical contribution to advance feasibility assessments by including actor perceptions and their evaluation of options in real world settings.

1. Introduction

The impacts of climate change are increasing across the globe (IPCC, 2022). The steep rise expected in climate risks will require societies to fundamentally change their risk management strategies (Garschagen and Kraas, 2010; Garschagen and Romero-Lankao, 2015; McPhearson et al., 2021; O'Brien, 2011; Pelling et al., 2015; Solecki et al., 2017). Adaptation to the increasing impacts of climate change cannot follow a "one size fits all" approach but will require societies to design context-specific portfolios of risk management solutions by selecting from an array of available adaptation options (Haasnoot et al., 2020, New et al., 2022). A major step on the way towards a strong social contract for adaptation (see Doshi and Garschagen, 2023 for details) is understanding how different actors view different adaptation options.

Progress has been made in understanding the strengths and weaknesses of different adaptation options, e.g. through a multi-dimensional feasibility assessment, as applied in the Intergovernmental Panel on Climate Change's (IPCC) Special Report 1.5 (IPCC, 2018) and Sixth Assessment Report WG II (IPCC, 2022). Such feasibility assessments make an important step in going beyond

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traditional cost-benefit analysis to also consider environmental, social, cultural, political and other factors. Yet, such multi-criteria evaluations so far have been focusing predominantly on individual adaptation measures and have aggregated the available information on their feasibility. They have not focused on two questions: first, how different actors perceive different adaptation measures and second, how different actors might view overall portfolios of measures differently rather than single options in isolation. At the same time, though, it is becoming increasingly clear that there is a fundamental difference between understanding individual options in isolation and evaluating entire portfolios of adaptation measures. As adaptation in most contexts will necessarily be composed of different measures in combination, the perspectives of different actor groups regarding their perceived needs and capacities as well as their actor-specific views on the pros and cons of different measures matter a great deal. Negotiating these views and designing portfolios of adaption measures includes difficult choices in setting priorities and navigating trade-offs – all of which might change over time. It is therefore important to understand how actors evaluate their perceived overall adaptation 'solution space' (Haasnoot et al., 2020; Stafford-Smith et al., 2022) since it is "socially constructed" and often "contested by actors with different norms, values, and interests" (Haasnoot et al. 2020, p.2). In doing so, it seems important to go beyond current feasibility assessment approaches not only in terms of actor-specific perspectives and adaptation portfolios but also in terms of separating the assessment of perceived desirability of options from the perceived feasibility. While these two aspects are often lumped together in current approaches (notably through integration of notions of social acceptance into the assessment of feasibility), it is becoming increasingly clear that actors often perceive and evaluate options differently with regard to desirability and feasibility and that an explicit focus on both is necessary in scientific assessments of adaptation.

Cities, in particular, exemplify the need for understanding how actors evaluate their perceived adaptation solution space as a whole and the desirability as well as feasibility of its individual measures. It is there that different viewpoints on adaptation options often clash most drastically, given that very heterogeneous groups come together, characterized by socio-cultural diversity, competing economic priorities, vested political interests, differing coping and adaptive capacities as well as risk perceptions. These characteristics influence the governance of urban adaptation including the negotiation of adaptation options and the roles and responsibilities for their implementation.

We take the coastal megacity of Mumbai, the seventh largest metropolitan city worldwide (UNDESA, 2018) and also the financial capital of India as a case study in this analysis. IPCC's Special Report on Oceans and the Cryosphere (SROCC) identifies Mumbai among the list of coastal cities including New York City, Tokyo, Jakarta, Shanghai and Lagos, that are at serious risk to climate change. Under RCP 8.5, without adaptation, a study estimates expected damages in Mumbai due to sea level rise to go up to $50 billion by 2050, making it the second most-at-risk city globally (Abadie et al., 2020). Mumbai is at high risk to flooding – driven not only by climate change and heavy rainfall but also by socio-economic and political factors affecting its exposure and vulnerability unequally. Despite the heavy pressure to adapt, studies show that responses have been inadequate (Singh et al., 2021), hence, more adaption needs to happen in the future if more severe risks are to be averted. At the same time, flood risk governance in Mumbai is complex and in many respects contested, with stark socio-economic inequalities, asymmetric power relations and conflicting political and economic priorities which influence how actors perceive and advocate different, often competing, risk management strategies.

In this analysis, we hence adopt an actor-oriented multi-dimensional framework to understand how different actors evaluate their perceived adaptation solution space. The aim is to understand which actors identify which adaptation options and how they assess their combinations into overall solution spaces. We use a multidimensional criteria framework to structure the actors' perceptions. We build on the feasibility assessment used in IPCC's sixth assessment report and explore the framework by applying it to the solution space for flood risk in Mumbai. Our analysis draws on empirical data collected through key informant interviews with state, civil society and academic actors.

Concretely, the paper has the following five objectives:

1. It lays out the adaptation solution space in terms of the perceived options.
2. The paper analyses which actors emphasize which types of options, differentiating between grey/physical infrastructure, green/natural infrastructure, institutional changes and hybrid options.
3. It analyzes how actors frame the overall desirability of the options. In other words, if they emphasize the option overall as desirable (positively), or not (negatively).
4. It examines in a multi-criteria fashion which feasibility dimensions are identified for which types of options and what role they are considered to play, i.e. as enablers and strengths or as barriers and weaknesses.
5. The paper assesses in-depth the role of institutional aspects hindering and fostering adaptation since these factors are considered most relevant by the actors.

The paper is structured in seven sections. The next part provides a conceptual background and elements of the analytical framework of the paper. Section three provides a brief context of flood risks and its current management in Mumbai. The fourth section outlines the method adopted for the data collection and analysis in this paper. Section five presents the main findings. Section six discusses these findings and highlights gaps and challenges for future evaluations of the adaptation solution space. The last section provides a conclusion and outlook.

2. Conceptual and analytical framework

2.1. Perceived adaptation solution space

The concept of the "solution space" can, in general terms, be understood as the menu of adaptation options that are potentially available (Du et al., 2022; Haasnoot et al., 2020; Sainz de Murieta et al., 2014). More precisely, the adaptation solution space is defined as "the space within which opportunities and constraints determine why, how, when, and who adapts to climate risks" (Haasnoot et al., 2020, p.2). In this analysis, we define the "perceived adaptation solution space" as the space comprising adaptation options as identified and perceived by actors in a given setting, in our case for flood risk in Mumbai. The boundaries of the perceived adaptation solution space are outlined by actors' perceptions on the overall desirability and feasibility of the adaptation options they identify, covering environmental, economic, technological, institutional, social and geophysical dimensions. A solution space is dynamic and changes over time because it is path-dependent due to earlier decisions or biophysical and socio-economic changes which influence the future availability and effectiveness of adaptation options (Haasnoot et al., 2020). Hence, the boundaries of the solution space are flexible and may change in composition (types of options, actor-based) and size (availability, desirability and feasibility) over time (Haasnoot et al., 2020).

2.2. Adaptation options

Adaptation options are actions or measures that are aimed at addressing identified adaptation needs (IPCC, 2014). There are several ways in which adaptation options may be categorized (Burton, 1996), according to the key risks they address (New et al., 2022), by sectors (health, agriculture and food, settlements), by types (structural, social, institutional), by mode (protect, advance, retreat, accommodate), by regions, scales (national, sub-national, local) etc. In the IPCC, adaptation options have recently been grouped into physical, natural and social infrastructures (Dodman et al., 2022). Inspired by these categorizations but also informed by our interview data, we cluster the identified adaptation options into grey/physical infrastructure (e.g. coastal defenses, flood barriers such as dykes), green/ natural infrastructure (ecosystem-based for e.g. mangrove protection), institutional changes (for e.g. inclusive planning, insurance) and hybrid (overlapping and/or combining the other three measures e.g. early warning technology and preparedness training). Options identified in this analysis include both existing measures as well as potential or envisioned solutions by the actors. Adaptation actions or measures essentially aim to limit or reduce climate risk, defined as a function of climate hazards, exposure and vulnerability (Garschagen et al., 2019). The effectiveness of adaptation measures can hence be assessed in terms of a measure's effect on hazard, exposure and/or vulnerability. Adaptation options may target to reduce both current and future risk, as well as one or more of its components to different extents (Garschagen et al., 2021). While we cannot conduct a comprehensive assessment of effectiveness of adaptation options due to data constraints, we present a heuristic application of the risk reduction associated with the perceived adaptation solution space.

2.3. Actors

In this article, we analyze the perceived adaptation solution space from an actor-oriented perspective. Given the socially constructed and contested nature of solution spaces (Haasnoot et al., 2020), understanding perceived solution spaces by different actors is critical towards building a coherent social contract for adaptation, i.e. an agreement in society on how to approach adaptation and share responsibilities (see Doshi and Garschagen, 2023 for details). An actor-oriented evaluation of the solution space helps to identify who perceives which options and how. This approach allows to show where actors may agree or disagree on different options and identify which options are highly contested. In this analysis, we aim to understand how key informants from three actor groups of most relevance for framing and shaping adaptation evaluate different adaptation options making up their perceived solution space: state actors, civil society and academia. Civil society organizations in the context of our study are taken in their role as spokespersons for the interests of vulnerable, often marginalized, residents of the city. Hence, an actor-oriented evaluation of the solution space helps to shed light on what is a quite messy field of different voices and viewpoints.

2.4. Multi-dimensional evaluation of adaptation options

In a next step, the analysis aims to show how different actors evaluate the list of identified adaptation options in terms of a multidimensional framework. According to (Haasnoot et al., 2020), the adaptation solution space is flexible and changing in response to factors from four dimensions – biophysical, cultural, socio-economic and political-institutional. In order to achieve more granularity, we use the multi-dimensional feasibility assessment of adaptation options by (Singh et al., 2020), also used in the Sixth Assessment Report of the IPCC (IPCC, 2022), as a heuristic to conduct an exploratory evaluation of adaptation options based on interview data. The feasibility assessment provides a scaffolding of six dimensions: environmental, economic, technological, institutional, social and geophysical. We extend the range of the social dimension to capture cultural and behavioural aspects and the institutional dimension to capture political aspects. This multidimensional assessment is an effort to move away from two practices which are currently predominant: first, a binary (feasible or not feasible) assessment of adaptation and second, a traditional cost-benefit analysis in selection of adaptation options (Fuldauer et al., 2022; Jafino et al., 2021; Singh et al., 2020).

Next to the perceived feasibility of adaptation options (i.e. "what is possible"), we explicitly analyze how actors perceive the desirability of adaptation options (i.e. "what is wanted"). In contrast to other feasibility assessments, we carve out the notion of

desirability from feasibility and assess it separately to show how actors perceive the overall desirability of identified options vis-à-vis their feasibility. We use the same six dimensions laid out above to structure the assessment of factors influencing the perceived feasibility and desirability of adaptation options. We hence divide each dimension into positive and negative aspects to assess how the actors emphasize the role of the dimension. Under a positive framing, we assess if an actor emphasizes the dimension as a strength or opportunity and sees the dimension as an enabling factor (Lehmann et al., 2015). A negative framing indicates that the actor emphasizes the dimension as a weakness, constraint or a barrier to the adaptation option (Adger et al., 2007; Biesbroek et al., 2015; Ford et al., 2017; Moser and Ekstrom, 2010). The evaluation may change over time and vary over spatial (global to local) and administrative (national to sub-local) scales (Singh et al., 2020). Aspects of different dimensions may also be seen to interact and reinforce each other – positively or negatively (ibid). For example, an advanced early warning system for floods could be positively influenced by technological as well as economic factors (technical capacity and budget or financial availability) while being negatively affected by institutional factors (e.g. lack of coordination between different administrative departments). Assessments of such relations could be useful in guiding policy makers in decision-making in terms of how the multidimensional, dynamic and interacting factors shape the adaptation solution space. Fig. 1 integrates the analytical elements and illustrates our assessment framework overall.

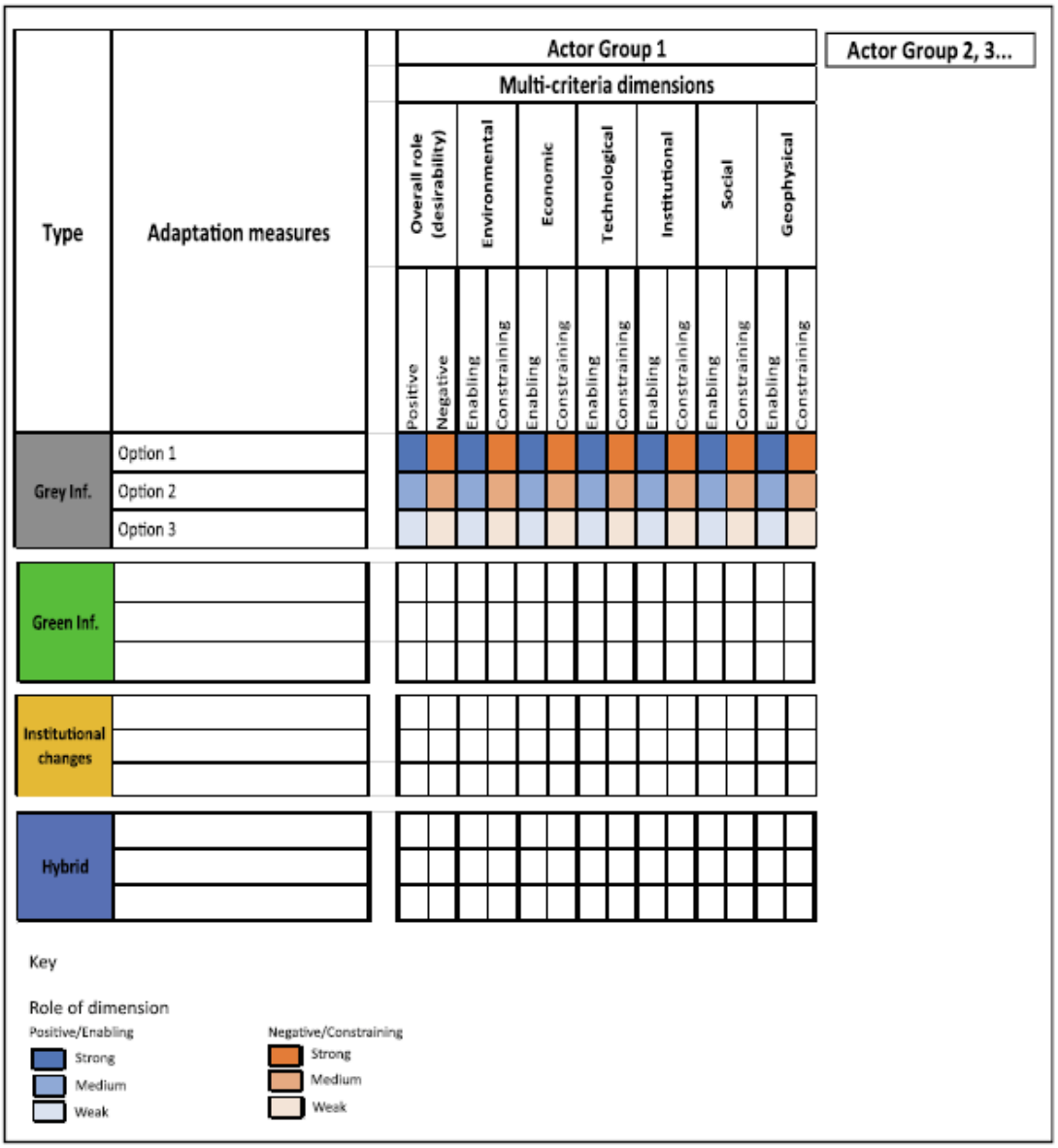

Fig. 1. Assessment framework for multi-dimensional assessment of perceived adaptation options from an actor perspective.

3. Flood risk and its management in Mumbai

Mumbai's flood risk is driven by climate change but also deeply rooted in its political economy, which defines the stark disparities in the residents' exposure and vulnerability as well as the contested landscape of current adaptation models and the steep socio-economic gradients in adaptive capacity (Dhiman et al., 2019; Ellis-Petersen, 2021, 2021; Gupta, 2007; Hallegatte et al., 2010). Mumbai experienced its worst flood in 2005, where 944 mm of rainfall fell in 24 hours, 1493 people died and loss estimates amounted to 1.7 billion USD. Although this disaster exposed the city's underlying vulnerability, it did not result in stopping maldevelopment (Cox and Cox, 2016). Flood intensity has been heavily driven by far-reaching soil sealing resulting in loss of natural ecosystems and floodplains (Pattaroni et al., 2022) as well as by inadequate solid waste management and poor maintenance of drainage infrastructure, causing the waterlogging and drain-clogging. Moreover, the financial capital of India is confronted with stark inequality. While wealth and power is highly concentrated amongst a comparatively small urban elite, over 40 percent of the city's population is living in informal settlements with high socio-economic vulnerability (Census of India, 2011). The high rates of land reclamation, soil-sealing and infrastructure development are primarily benefiting the urban elite and emerging middle-classes, but low-income and marginalized populations are often forced to live in flood-prone areas without formal land titles and excluded from basic civic infrastructure such as waste collection. They are hence not only over-proportionally affected by flooding but typically also blamed for causing waterlogging, and, on these grounds, often even evicted or further cut in their support (Chatterjee, 2010; Parthasarathy, 2003).

In addition to these inequities in the production of risk, the responses to current and future flood risk are also contested in Mumbai. The formally encoded distribution of roles and responsibilities for flood risk management remains ambiguous in a number of respects and leaves room for interpretation according to political priorities rather than a rights-based approach. According to core national legislation and the corresponding plan, responsibility for disaster risk management is decentralized to a District Disaster Management Authority (Disaster Management Act 2005, 2005). This led to the creation of the Greater Mumbai Disaster Management Authority (GMDMA). However, since Mumbai comprises two administrative districts (Mumbai City and Mumbai Suburbs), in 2017 the Bombay High Court dismissed the GMDMA and instead ordered the creation of two District Disaster Management Authorities – one for the city and one for the suburbs. However, their de facto roles and responsibilities were questioned (Bhide and Kamble, 2020). The Disaster Management department of the municipal authority (MCGM) is a key stakeholder in flood risk management. According to Flood Preparedness Guidelines released every year by the department, it is entrusted with various activities for emergency response, preparedness and prevention. For example, directing the early warning system comprising of rain gauges and flow level sensors in rivers to issue early warnings to citizens through a disaster management app, website or social media. While the local municipal authority is entrusted with emergency response functions, national guidelines on urban flood management (UFM) foresee the role of citizens as first responders, even before the state steps in. Other departments of the MCGM such as environment, storm water drainage, sewage and waste disposal, transport etc. are also involved in direct or indirect activities towards flood risk management. The city's central flood risk management response is the Brihanmumbai stormwater drainage systems project (abbreviated as BRIMSTOWAD hereafter) which falls under the storm water department of MCGM (Gupta, 2007). However, the State Action Plan for Climate Change has identified the inadequacy and ineffectiveness of the drainage system as a driver of flooding (Arunachalam, 2005; Sansare and Mhaske, 2020). The city recently adopted the Mumbai Climate Action Plan, commissioned by the MCGM to World Resources Institute (MCGM, 2022). Although the plan marks an important milestone in the recognition of climate change by state authorities at the city level, it has been questioned for being a top-down plan developed by an external consultancy (Wagh and Indorewala, 2022). The (somewhat uneven) public consultation sought in the process of developing the plan was criticized - "Formulating a climate emergency plan requires a collective effort, through a deliberative consensus building process, rather than networking and partnering with a willing audience." (Wagh and Indorewala, 2022).

Formal flood mitigation strategies often do not benefit the people living in slums. On the contrary, slum dwellers are often displaced for making space for infrastructure projects that benefit the better-off parts of society (Chatterjee 2010). Resettlement and housing issues of informal settlements are intertwined with state-led physical infrastructure approaches to flood risk management which often result in evictions of marginalized settlements (Mehta et al., 2019). Given the lack of municipal action, vulnerable populations are adapting to floods autonomously (Patankar, 2019, 2015; Schaer and Pantakar, 2018). They resort to informal mechanisms of risk management and employ strategies such as raising floor heights, constructing elevated levels to store equipment, building temporary flood barriers etc. which are, however, rather reactive, ineffective and inadequate responses to the rising flood risk (Singh et al. 2021). Previous studies have emphasized the important role of civil society organizations in coping with flooding in Mumbai (Chatterjee, 2010; Singh et al., 2021). In addition, vulnerable populations would rely on multiple sources of support ranging from state, private sector, NGOs and social support networks – access to which, however, is often hampered by barriers in terms of socio-economic status and lacking social capital (Chatterjee 2010).

The urban elite also plays a dominant role. Parthasarathy (2003) argues that urban elites support exclusionary civic policies against the interests of the poor. A recent example of elite capture was seen in the contestations around the highly controversial publicly funded Coastal Road infrastructure project perceived to serve the elite. The project succeeded despite protests against it due to its adverse impacts on the sensitive coastline and livelihoods of fishing communities (Mumbai Mirror, 2019). Despite being highly exposed to the impacts of sea level rise and having a Coastal Zone Regulation law to protect the coastline, critiques have pointed out how the law has been steadily weakened and concerns raised by activists and academics have been ignored (Chouhan et al., 2016; EPW, 2015). This example suggests that there are wide gaps in the ways different actors think about the desirability and feasibility of adaptation measures and that laying these rifts open is much needed to move effective and equitable adaptation forward. However, the different perspectives have so far not been studied in an explicit and structured manner.

4. Methods

4.1. Data collection

This actor-oriented multidimensional evaluation of adaptation options draws primarily on qualitative data collected in the form of semi-structured interviews with key informants and stakeholders across state actors, civil society organizations and academia working on flood risk management in Mumbai. Actors were identified based on a review of scientific and grey literature e.g. government reports, planning documents and media articles as well as snowballing. The interviews took place against the backdrop of the development of the Mumbai Climate Action Plan (MCGM, 2022) which supported the snowballing process and elicited the interest of several actors, especially from the state to participate in an interview.

This analysis draws on interviews with 37 key informants - 11 from state institutions, 12 from civil society organizations and 14 from academic institutions. State actors ranged from officials at the Maharashtra state government to the metropolitan planning authority (MMRDA) and the municipal city authority (MCGM) including its key departments e.g. disaster management, environment and storm water drainage. From civil society, we interviewed actors working on a range of issues including environmental justice, social vulnerability in informal settlements and ecosystem protection. Journalists from major mainstream newspapers were also interviewed. Civil society actors were seen to speak on behalf of vulnerable groups, although it must be noted that this might not give a complete representation of all vulnerable groups given the specific foci of different organizations. We aim to triangulate this research with other methods such as household surveys in the future. Academic actors included professors at the city's leading institutes but also independent researchers in think tanks and international organizations. We used a semi-structured interview guide in order to create comparability whilst allowing topics to emerge from the interview.

The data collection process started with invitations for remote interviews in December 2020 due to pandemic-related travel restrictions. However, due to the ongoing pandemic and a particularly devastating second Covid wave in India between February and April 2021, only six remote interviews could be conducted between May and August 2021. The interviews with a majority of the experts were conducted in person in Mumbai between September and November 2021 and April and May 2022. Duration of the interviews were approximately 35 to 40 minutes, ranging from 25 minutes to almost 2 hours.

4.2. Coding and analysis

For in-depth qualitative content analysis of the interviews (Mayring, 2000), all transcriptions and hand-written notes (where recording was not allowed) were analyzed using MAXQDA, a qualitative data analysis software. Interviews were coded following a grounded-theory approach with inductive as well as deductive codes (Glaser and Strauss, 1967). A coding scheme was initially developed according to the questionnaire and revised in the subsequent rounds of coding.

After coding the interview data, we analyzed all coded segments and subsequently mapped them onto the multidimensional framework. In a first step, identified adaptation options were divided according to the actors who emphasized them - i.e. state, civil society or academia. In a next step, we clustered the options according to their type i.e. grey/physical infrastructure, green/natural infrastructure, institutional changes or hybrid options. We grouped the options into one of these types depending on the way in which actors described them. For example, if an actor emphasized social housing in terms of the policy changes needed to facilitate its implementation, we categorized it as an institutional change. On the contrary, if an actor highlighted the physical infrastructure needed as well, we grouped it under a hybrid option. The options were analyzed in three steps. First, each option was assigned an 'overall desirability' depending on whether the actors emphasized the option as desirable (positive) or not (negative). Second, we mapped the feasibility of the options in terms of whichever of the six dimensions that actors had emphasized. We further indicated if the actor identified the dimension as playing a positive, enabling role or a negative, constraining role. In order to provide an overview of the actor-oriented multi-dimensional evaluation, we illustrate the framework in Fig. 1.

5. Results

5.1. Options making up the perceived adaptation solution space

Overall, the actors identified 219 adaptation options, with almost two-thirds (60%) being institutional measures (Table 1). A large majority of the options are governance-related, thus indicating the perceived importance of such aspects for overall adaptation to flood risk in Mumbai. Actors particularly called for increasing institutional capacity, public participation, holistic planning and for a shift in the narrative and understanding of the flood risk problem. Some of the lesser emphasized institutional changes included regulations, changes in media reporting of flooding, investment for measures, increasing individual capacity and awareness. Grey/physical infrastructure options made up a quarter of the portfolio of adaptation measures. This is largely because technical engineering approaches form the predominant response of the city to control flood risk. Since the storm water drainage system (BRIMSTOWAD) project is the major state-led flood risk management strategy, many actors highlighted a number of individual sub-measures implemented within this project e.g. pumping stations, retention walls etc. Infrastructure projects were mostly discussed on a rather generic level. They received both positive statements, e.g. emphasizing the need for retrofitting infrastructure, and negative valuations, e.g. calling for the suspension of capital intensive projects such as the Coastal Road. Surprisingly, only 10% of the identified options are green infrastructure measures despite the loss of ecosystems being a major driver of flood risk in Mumbai. Among these options, actors prioritized the protection of existing ecosystems such as mangroves, wetlands and creeks. Other options focused on the need to revive

Table 1
Overview of types of adaptation options making up the solution space.

Type	Category of options	Examples of options	Total share
Grey/ Physical Inf.	BRIMSTOWAD and drainage system	Storm water pumping stations; Holding tanks; Retaining walls; Drainage system	11
	Flood barriers; dykes; dams	Seawalls	8
	Forecasting and early warning	Doppler radar; IFLOWS	2
	Infrastructure projects	Elevation of infrastructure projects	2
	Engineering solutions	Refers broadly to technical fixes, civil engineering solutions, technology in flood risk management	1
Green/ Natural Inf.	Ecosystem based measures	Landscaping strategy	0
	Increased percolation	Need to allow open spaces for percolation	1
	Protection of ecosystems	Protection of ecosystems such as mangroves, wetlands, river ecology etc.	1
Institutional changes	Awareness	Awareness and sensitization to climate change at governance levels	0
	Governance	Housing and resettlement policies, overhaul of the urban development ministry, social impact assessment for projects etc.	23
	Individual capacity	Household based adaptation measures, training people in following early warnings, local knowledge etc.	1
	Institutional capacity	Creation of an online platform or network for sharing solutions between researchers, practitioners and policy makers, multi-disciplinary teams in state departments etc.	3
	Investment	Increased investment in disaster preparedness, public transport and mangrove protection	2
	Media	Prioritizing environment and climate change in mainstream newspapers, developing skilled reporters in these topics, changes in media coverage of flood events in Mumbai	0
	Planning	City plans to account for flood control, inter-linkage of MCAP and DP, planning for retreat and resettlement of coastal populations etc.	13
	Public participation	Creation of citizen collectives, participatory planning in MCAP, public consultations through Area Sabha etc.	4
	Regulations	Coastal Zone Regulations (CRZ), changing building laws, strengthening environmental legislation in the DP etc.	3
	Shift in narrative/understanding	Re-define the problem, call for paradigm shift, shift in narrative and understanding, etc.	10
Hybrid	Green/Grey	Sponge city, coastal barrier (similar to New York)	1
	Institutional/Green	Re-look at the role of ecosystems	0
	Institutional/Grey	Housing policies, re-looking at the BRIMSTOWAD proposal, Engineering training etc.	5

water bodies, increase percolation and adopt softer landscaping strategies. Actors also emphasized the need to recognize the role of ecosystem services in options on institutional changes e.g. in land-use planning and climate resilient plans. Hybrid options make up the smallest share in the overall portfolio, with less than 10%. These include options which combine one or the other types of measures together, e.g. 'sponge city' approach which equally deserve grey and green infrastructure retrofitting as well as deeper institutional changes.

In terms of the intended effect on risk and the mechanisms for risk reduction, the portfolio of identified measures reveals a mixed picture. We find that largely grey and green infrastructure options are intended to address hazards and exposure (Fig. 2). However, some civil society and academic actors also noted the negative role of selective engineering options e.g. retention walls which induce a false sense of security and end up increasing exposure. Similarly, respondents mentioned drainage systems with restricted capacity due to solid waste and limited effectiveness to mitigate flood hazards. Interestingly, we did not find many options targeting social vulnerability except within a few options under institutional changes, e.g. the call for participatory and inclusive planning by a handful of civil society and academic actors.

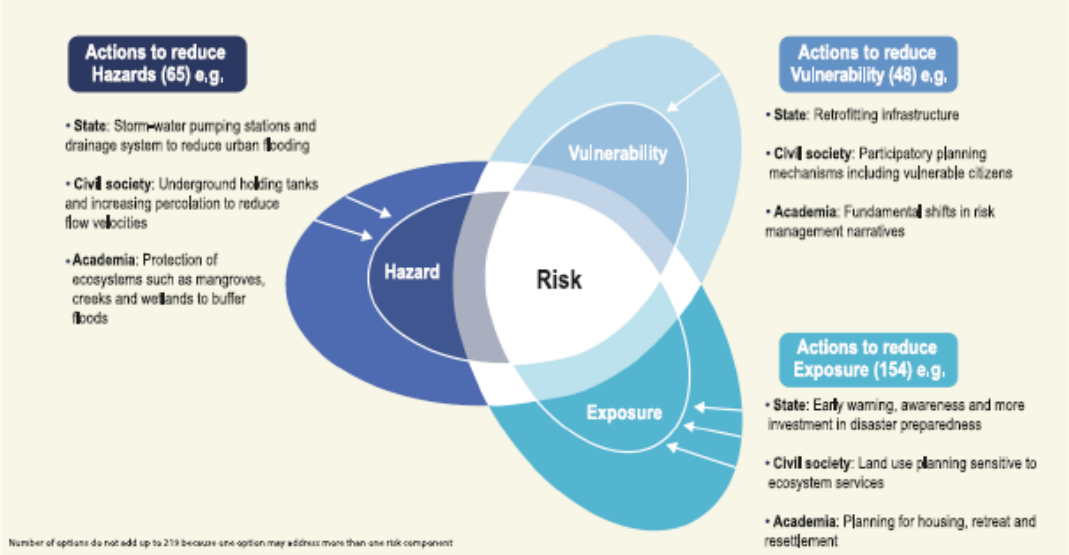

Fig. 2. Conceptual relation of adaptation options on reducing risk and its elements (adapted from Garschagen et al., 2019).

5.2. *Perceived adaptation solution spaces by different actors*

Overall, state actors largely emphasized engineering options (50%), followed by institutional changes (25%) (Fig. 3). The emphasis on physical infrastructure could be explained by the dominance of technical measures in the state's response to flood risk management in Mumbai. Examples include various measures in relation to the BRIMSTOWAD project e.g. construction of holding tanks, pumping stations, retention walls along drainage channels and machinery required for the annual drainage cleaning before the monsoon. More than half of the state actors highlighted institutional changes including calls for more investment in disaster preparedness, city plans to account for flood control, an online platform for exchanging best practices etc. Hybrid options such as the need for low-cost housing and rehabilitation which require both policy and building infrastructure were identified. Two state actors stressed green options, especially protection of ecosystems that play a crucial role in mitigating flood hazard e.g. mangroves, wetlands and creeks.

Civil society actors identified 42% of the overall number of measures, highlighting their active role in the debate. All civil society actors emphasize institutional changes - making up 64% of their portfolio. They called for more public participation in terms of participatory planning in the Development Plan and Mumbai Climate Action Plan, a stronger dialogue between civil society and planners to recognize people's interests and open up a discussion of transformation, allowing for public consultations through local governing bodies, a collective visioning process etc. Along with academia, a majority of civil society actors also emphasized several governance-related measures, e.g. protection of buffer zones along the Mithi River, inclusive policies for housing, or the incorporation of climate change concerns in infrastructure projects (similar to an Environmental Impact Assessment). Almost half of the civil society actors called for a stronger emphasis on ecosystem protection. Hybrid options included measures on housing and slum re-development and a green-grey measure inspired by the Coastal Barrier in New York.

Academic actors contributed significantly to the width of the overall solution space (47% of the mentioned measures overall), with institutional changes making for the biggest block. A majority of academic respondents called for governance reforms, changes in land use planning and governance reforms to reconfigure the power relations, roles and responsibilities of different departments and actors in the administration of the city. Complementing civil society actors' call for increased public participation through local governing bodies, a few academic actors also discussed the potential of urban local management through so-called 'urban local bodies'. Furthermore, almost half the academic actors pushed for comprehensive land use planning by re-evaluating planning norms and urgently re-visiting planning goals, e.g. to recognize the role of ecosystem services. At the conceptual level, more than half of the academic actors indicated the need for a paradigm shift - in narrative, mindset, attitude, perception and approach towards flood risk management. For example, they called for a re-definition of the problem, shift from focusing on extreme events to everyday flood events and a fundamental shift from the current "resistant model" of flood risk management.

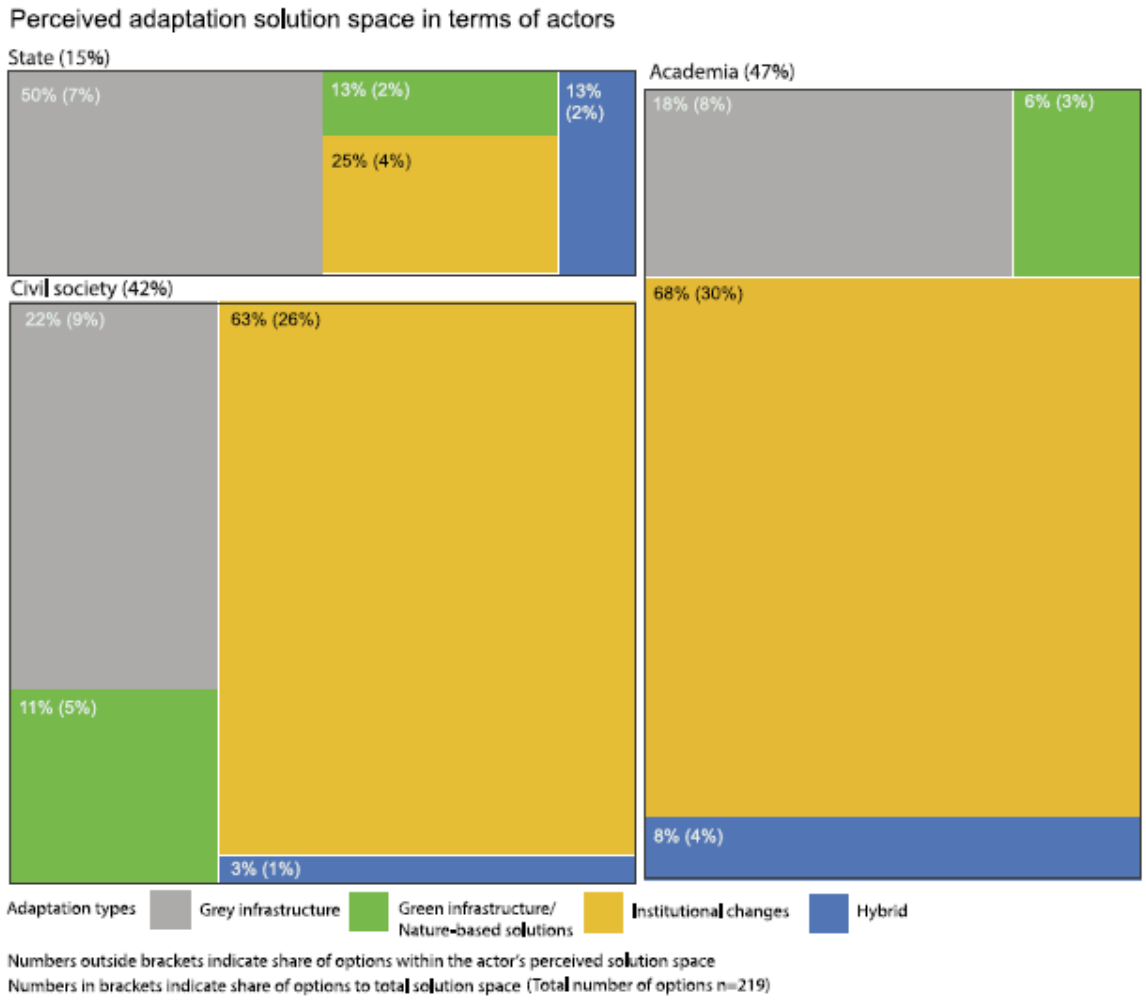

Fig. 3. Perceived solution spaces by actor groups comprising different adaptation types.

5.3. Consensus and contestations between actors regarding the desirability of options

Out of all adaptation options, the clearest agreement between state, civil society and academic actors is seen on the positive desirability of green options - especially the need for protection of ecosystems such as mangroves, creeks and wetlands as well as the reinstallation of open surface areas for water infiltration (Fig. 4). However, one civil society actor cautioned the need to also maintain ecosystem-based options in order to prevent them from becoming maladaptive, citing an example of siltation in holding ponds.

The majority of actors perceive institutional changes as desirable, albeit a few exceptions. State actors highlight the need for planning and policies for low-cost housing, sensitization of citizens and state actors in a leadership role and more investment in preparedness. However, one state actor emphasized the challenges associated with increasing migration and rehabilitation. Largely, civil society and academic actors emphasize governance-related measures positively. A civil society actor raised concerns about resettlement as an adaptation strategy for vulnerable populations. The argument was twofold: firstly, resettlement was viewed negatively due to the repeated need for temporary resettlement after each flood. Secondly, even if the option of permanent rehabilitation was available, the social acceptance for such a move was questioned. Although planning in general is viewed positively, half of the civil society actors expressed their critique of the participatory planning process of the MCAP and its potential impact. They suggested that the plan needed to be integrated in the Development Plan 2034 of Mumbai to achieve its desired outcomes. Almost half of all actors stressed the significance of changing the narrative and understanding of flood risk management. Yet, one academic actor voiced concern about the use of adaptation terminology and its potential to restrict empirical insights. Broadly, academic actors called for a regional, holistic understanding of the problem, fundamental shift in narrative, perception and approach to flood risk management.

On the role of physical infrastructure measures, we find a strong divide between state actors on the one hand and civil society and academia on the other. Almost half of the state actors frame physical options as desirable, particularly BRIMSTOWAD, while only one

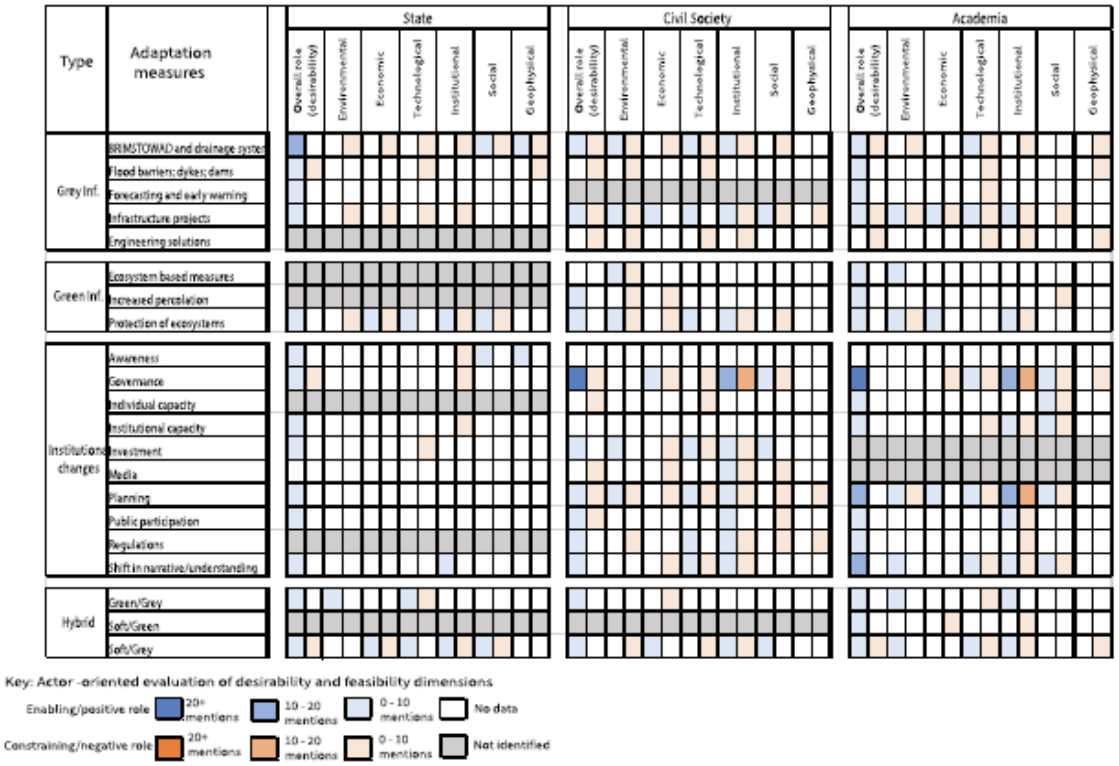

Fig. 4. Heuristic mapping of actor-oriented multi-dimensional evaluation of adaptation options based on interviews.

actor from the State Mangrove Cell acknowledged the adverse impact of sea walls in flood protection. Civil society and academic actors argued that state actors desire engineering measures for the following reasons: first, the possibility of profit motives associated with the large investments needed for technical projects; second, the dominance of civil engineers in state authorities (which may lead to absence of ecosystem considerations in grey infrastructure projects); and third, conflicting priorities and lock-in effects created due to path dependencies of such infrastructure measures. In contrast to state actors, more than half of civil society and a few academic actors view BRIMSTOWAD-related measures negatively and also highlight the need for stopping capital intensive infrastructure projects that lead to severe destruction of important ecologies e.g. the Coastal Road. Contrary to a state actor who indicated that it might become necessary to consider a dyke structure, many civil society and academic actors strongly criticized sea walls and similar structural measures with one actor suggesting flood barriers "to be like trying to piss on a forest fire".

A few academic actors perceived engineering solutions as technocratic fixes, piecemeal in nature and in some cases even maladaptive. They argued that such measures have worsened the problem of flooding instead of reducing flood risk. Six civil society and two academic actors also acknowledge the positive role of particular physical options e.g. rainwater harvesting, thrash brooms, implementation of the sewage system proposal and the need to elevate all infrastructure. One state actor emphasized the need for ultimately retrofitting infrastructure considering that the city is completely developed in terms of built-up area. Ultimately, some actors acknowledged the need for hybrid solutions- especially combining physical and natural approaches, recognizing that engineered solutions alone would not be enough because they are designed for certain thresholds which essentially get challenged.

5.4. Multi-dimensional evaluation of adaptation options

In terms of the actors' evaluation of adaptation options, we observe considerable differences in the strength with which they consider and emphasize different evaluation dimensions (Fig. 4). Overall, institutional dimensions clearly outweigh the other dimensions by making up 44% of all evaluations, positively (21%) and negatively (23%). The next section unpacks the institutional dimensions in detail. Similarly, environmental dimensions received an equal weightage in terms of both, their positive and negative role (6% respectively), although much less emphasized than institutional factors. On the positive role, actors emphasized the benefits of ecosystem services on reducing flood risk, whereas they also noted the challenges to ecosystem protection by increasing concretization.

A common trend emerges for technological, economic, social and geophysical dimensions, where their constraining role is emphasized more than their enabling role. For technological dimensions, on the one hand, actors highlighted technical limitations in infrastructure projects in view of climate change and local drivers of urbanization. On the other hand, they also noted the need to

modify technical aspects in building design, land use planning and flood protection measures. Economic dimensions in terms of budget constraints for capital intensive projects, rising costs, competing economic priorities in urban development etc. were emphasized by actors. Yet, actors also note a minor positive role of economic dimensions in enabling adaptation measures, such as profit making motive of the private sector, cost effectiveness of different adaptation measures or being the financial capital of the country. Actors highlighted the constraining role of social dimensions in terms of stark social inequalities, lack of awareness, public participation, power relations etc. However, the enabling role of social aspects such as consideration of vulnerable groups and impacts on their livelihoods, collective knowledge and responsibility of different social groups etc. were also acknowledged by some actors. Finally, actors viewed geophysical dimensions such as sea level rise and changing rainfall patterns to play a constraining role in the implementation of adaptation options.

In terms of evaluating different types of adaptation options, we find different dimensions being emphasized and to varying extents. On the evaluation of physical options, there is a striking emphasis on the negative perspectives, spanning across all evaluation dimensions but to a different degree. Technological evaluation dimensions in particular are seen to contribute to a negative picture, e.g. with regards to hard limits of infrastructure which are seen as a risk. Social dimensions in relation to physical infrastructure, e.g. the impacts of hard infrastructure on social vulnerability, were not much discussed – but indirectly come to the fore in terms of institutional dimensions such as participation in planning, discussed below. For green infrastructure options, a mixed picture emerges. While environmental dimensions are seen to play a largely enabling role, many institutional and economic factors such as weak governance mechanisms and competing economic priorities of land use are indicated as constraints for ecosystem-based options. Not surprisingly, the evaluation for institutional change related measures shows a clear emphasis on institutional dimensions, indicating governance aspects playing a strong enabling and constraining role. Actors identified the lack of consideration of social vulnerability factors as a weakness in the evaluation of institutional changes. Technical aspects of hard infrastructure measures were seen to constrain many institutional changes, notably due to infrastructure lock-in and path dependencies created by engineering measures. In the case of hybrid options, actors emphasized institutional dimensions as challenges, e.g. policy changes and technical constraints. However, actors also identified capacity and technical resources for hybrid options, including learning from measures implemented in other countries.

Comparing the roles different dimensions play across different actors' evaluations, a quite complicated but very informative picture emerges, highlighting what matters most for different actors when they judge different adaptation options. State actors strongly highlight the constraining role of environmental dimensions for infrastructure measures, e.g. solid waste pollution as a problem for drainage and pumping infrastructure. Both state and civil society emphasize economic dimensions as challenges, yet differently. While state actors emphasize the challenge of costs of adaptation measures, civil society point out economic vulnerability, vested financial interests and political economy of urban land use planning aspects. All three actors show agreement in the constraining role of technological dimensions for adaptation options. In terms of institutional dimensions, state actors identify current policies e.g. relating to land ownership, rehabilitation and redevelopment, and legal protection of ecosystems as a constraining factor. Civil society and academic actors highlight institutional dimensions in both their enabling role, especially for potential adaptation options as well as their constraining role in past and current approaches. Civil society and academic actors highlighted that social dimensions are of great importance to them but are, in their view, currently not sufficiently considered in formal adaptation planning, for example, with respect to considering the impacts of adaptation measures on social vulnerability.

5.5. *Unpacking the pivotal role of institutional dimensions*

Given the strong emphasis actors put on institutional dimensions in their overall evaluation of the solution space, this section aims to unpack specific enabling and constraining roles of institutional factors. On the positive role of institutional dimensions, most state actors highlighted political and legal aspects in enabling adaptation, e.g. in the provision of low cost housing and protection of mangroves. A vast majority of civil society and academic actors emphasize the enabling role of institutional dimensions across all four types of options but most strongly for institutional changes. They also call for an increase in public participation and an intensification of regulations for protection in order to enable a paradigm shift from the current high-risk development trajectory of the city. Examples of institutional adaptation include re-defining the value of land in formal state-led city planning by assigning higher importance to natural ecosystems, making preparedness a political priority in agendas of political parties and a new public discourse and narrative in thinking about urban informal settlements. Many actors suggested governance mechanisms to decentralize planning and include vulnerable populations in planning at local levels. Some academic actors highlighted the need for governance reforms that target the way the city is administered and the bureaucracy in managing flood risk. Additionally, a few civil society actors pushed for protecting the violation of important regulations such as the Coastal Regulation Zone law or changing planning regulations to prevent maladaptation, e.g. by introducing a "climate stress test" at the planning level for technical infrastructure projects.

Despite the enabling role of institutional dimensions, actors also discuss how institutional aspects may constrain different adaptation measures. Almost half of all state actors strongly emphasize the negative role of institutional dimensions for institutional change options. One state actor indicated the need for stopping or minimizing migration, yet noted the influence of political aspects in controlling migration because migrants were viewed to constitute more than 30% of the vote banks. Some state actors identified a lack of awareness at the "helmet level" and a lack of collaboration and network as weaknesses in governance, e.g. in the exchange of best practices in ecosystem protection. Civil society actors highlighted the gap in policy making for low cost housing and pointed out the need to become inclusive. While they cited a lack of political will in providing civic services for the urban poor to help them adapt, they also acknowledged that political will and funding would only be channeled if there was enough public demand. One actor went on to identify that a fundamental challenge lies in the institutional perception of vulnerable populations not as citizens but as "encroachers". Many academic actors stressed the weaknesses in institutional mechanisms related to social housing, resettlement and retreat of

vulnerable populations. A few actors pointed out institutional bottlenecks in the overall adaptation solution space, highlighting the dominance of engineering training and a lack of acknowledgement of local knowledge. They identified a huge gap in institutional capacity of planning and execution authorities beyond engineering which often results in technical defense responses in mitigating flood risk. They stressed the need for multidisciplinary collaboration between different stakeholders to allow for social and ecological concerns and indigenous solutions to be incorporated in decision-making and planning.

6. Discussion

In total, our analysis aimed to understand which different adaptation options actors identified and how they evaluated them using a multi-dimensional framework. Five key findings emerged:

First, among all options, actors most strongly emphasize the desirability of institutional changes. While this option features more dominantly in the portfolios of civil society and academia, they make up roughly a quarter of the state actors' portfolio of adaptation options. Examples of measures range across governance reforms, planning, regulations, public participation, institutional arrangements for investment etc. A majority of institutional changes push for a more fundamental shift not just in the approach to flood risk management but in the larger development paradigm for Mumbai, e.g. re-evaluation of land use planning and regulations, overhaul of entire departments within the administration, fundamental shift in risk perceptions and re-visiting the role of ecosystems.

Second, all actors show a strong agreement regarding the overall desirability of nature-based options, despite the fact that these options make up for a very small share of the portfolio and are seen to be challenged by major institutional and economic constraints. The small portfolio fraction is partly due to the fact that some ecosystem-related measures have been categorized as institutional changes in the analysis because actors emphasized the role and importance of ecosystems in planning and call for fundamental changes in risk perception, narratives etc.

Third, on grey/physical options, we find a split between different actors' perceptions. While a large majority of state actors emphasized them positively, civil society and academia mostly point out the challenges of engineering measures. Many civil society and academic actors stress the ineffectiveness and in some cases even maladaptive effects of engineering measures and large infrastructure projects in mitigating flood risk, in line with current literature (e.g. Senapati and Gupta, 2017).

Fourth, on the multi-dimensional feasibility of options, our analysis shows that institutional dimensions are seen to play a pivotal role to enable as well as constrain adaptation options. This finding confirms arguments in the literature on the importance of institutional change in fundamental, transformative shifts in adaptation to climate change (Kinley, 2017; Njuguna et al., 2022).

Finally, we find a less clear picture in terms of how actors consider and agree on other dimensions in their evaluation of adaptation. We did not find a strong consideration of social, cultural and behavioural dimensions in the evaluation of adaptation options. Even social justice and equity considerations were largely absent, despite the fact that they are in the literature discussed as being highly relevant (Adger et al., 2007, 2006; Araos et al., 2021). However, social considerations are indirectly considered in a handful of options, e.g. the call for increased public participation and recognition of citizen voices. Interestingly, although one would assume economic dimensions such as financial resources to act as a strong enabler or barrier in the selection of adaptation options in Mumbai, our analysis finds a weak consideration of economic dimensions by actors. An explanation for this gap could be inferred from the fact that even though some state actors highlighted budget constraints, many civil society and academic actors did not view financial resources as a constraint but instead the vested economic interests in real estate which influences land use planning. In other words, political will and institutional dimensions were seen to play a stronger role. Furthermore, it is also interesting to note the lack of recognition of geophysical limits to adaptation options.

While this analysis provides relevant insights using the actor-oriented evaluation of the adaptation solution space within the multi-dimensional framework it is not without limitations. First, although the analysis does not capture effectiveness of adaptation options, this dimension could be added to the framework in future research. Second, this analysis provides a snapshot of the actor-perceived solution space and does not capture temporal changes (Haasnoot et al., 2020; Mechler and Schinko, 2016). However, the approach could be applied in different time steps to capture changes over time and analyze changes in actors' perspectives on the desirability and feasibility of adaptation measures.

7. Conclusion and outlook

In this paper, we aimed to explore how different actors evaluate their perceived adaptation solution space by using the multidimensional assessment as a rough heuristic guide in the analysis (Singh et al. 2020). There is a need to understand how actors perceive different adaptation options and evaluate them for criteria beyond binary assessments and traditional cost-benefit analyses. This includes the consideration of aspects such as social acceptability, political and institutional environments, physical and technical measures, geophysical limits, environmental conditions and wider economic factors. In this regard, we explored an empirical application of the framework to analyze perceived urban adaptation options for flood risk management in Mumbai, collected through key informant interviews with state, civil society and academic actors. The study is embedded in the context of a growing need to understand how societies will achieve a coherent social contract for adaptation by agreeing on a clear distribution of roles and responsibilities for different adaptation options (see Doshi and Garschagen, 2023 for details). The next step in this research is to identify roles and responsibilities ascribed by actors for the identified adaptation options.

Overall, the study finds a strong emphasis on institutional elements – both in terms of institutional adaptation measures considered necessary and the pivotal role of institutional dimensions in evaluating the desirability and feasibility of grey and green infrastructure measures. In terms of other adaptation measures, there is a strong consensus on the positive role of nature-based options, even though

they so far have been playing a minor role in the city's overall adaptation portfolio. Contrary to the agreement on green / nature-based options, we found strong actor divides on the grey/physical options. This is an important finding considering that grey/physical options form the dominant approach of formal state-led flood risk management in Mumbai to date. Among the other dimensions, there is a weak consideration of social vulnerability reduction in adaptation options and equity as well as social justice aspects in most actors' evaluation of different adaptation options. This is surprising given the active participation of civil society actors and academia. Yet, there is a strong call for public participation in planning mechanisms which could potentially be the basis for increasing the consideration of social vulnerability as well as cultural and behavioural aspects in evaluating adaptation options. The actor-oriented evaluation of perceived solution spaces is hence a critical step forward but needs to be advanced through future research.

This study makes a conceptual and empirical contribution to advance the evaluation of adaptation options by including actor perceptions and their evaluation of options in real world settings. The analysis uses the IPCC multi-dimensional feasibility assessment as a heuristic guide and extends it in four key ways: First, we applied an actor-oriented approach to capture how different actors consider and evaluate the available adaptation options in their perceived adaptation solution spaces. Second, the work shows that mapping and comparing actors' evaluations of different adaptation options and rifts in the perceived "right-mix" of options is a critical part of understanding and shaping overall solution spaces in a structured manner. Third, we separated the assessment of desirability from feasibility in order to examine whether and how actors' views on "what is desirable" differs from "what would be possible". Finally, this study makes a step beyond the current literature which tends to focus on "barriers to adaptation" (Biesbroek et al., 2015) by focusing also on the factors perceived to enable adaptation, structured into environmental, economic, technological, institutional, social and geophysical dimensions. We argue that such actor-specific and subjective perspectives on perceived feasibility and desirability need to be included into the scientific evaluation of adaptation options more strongly in order to increase the usefulness of "feasibility assessments" and inform adaptation governance.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Guiding questions for the semi-structured interview:

What is your opinion on the current state of adaptation to flood risk in Mumbai?
In your expert opinion what needs to be changed most urgently in flood risk management in Mumbai and why?
What would be your vision for Mumbai in terms of successful flood risk management?
What is preventing Mumbai from transitioning into that vision?
What are ways to overcome these challenges?

*Please note that questions were kept broad to allow for follow-up questions and the interviewee to bring up topics which were relevant in their opinion.

See Tables A1 and A2.

Table A1
Guiding questions for the "heuristic mapping of actor-oriented multi-dimensional evaluation of adaptation options based on interviews".

Steps	Explanation	Guiding questions	Assessment	Corresponding code
Identification and categorization of adaptation options	The first step involved identifying adaptation options that the experts talked about and categorized them into the following types (based on IPCC AR6 Chapter 6): 1. Social infrastructure, 2. Nature-based solutions, 3. Grey/Physical infrastructure. We added a fourth category, developed bottom-up from the data – 4. Hybrid options (which combined one or more of categories 1-3).	Which adaptation options are identified? Which category does the identified adaptation option fall into?	1. Institutional changes 2. Nature-based solutions, 3.Grey/Physical infrastructure 4. Hybrid options	Type
Actor-based identification of adaptation options	In a next step, the actor who identified the respective adaptation option is categorized.	Which actor identified which adaptation options?	State Civil society Academia	Actor
Overall desirability of the adaptation options	We aim to capture the overall role in which the actors emphasize or discuss the identified options, i.e. positively, negatively or mixed. In other words, we split the notions of desirability and feasibility of the identified options – in contrast to Singh et al. who combine both under "feasibility". They capture desirability to some extent under the social dimension of socio-cultural acceptability. Furthermore, they justify it on the grounds of not being able to capture desirability of an option based on a global assessment of adaptation options, given the actor/context based nature of desirability. However, in this case, we see merit in disaggregating the characteristics of desirability and feasibility because an actor may perceive an adaptation option as highly desirable (and hence categorized in the analysis as overall positive), although it may not be seen as highly feasible. The reverse could also be true where actors may perceive an option as not desirable (and hence it would be categorized as negative), despite being highly feasible for eg. in terms of economic resources and technical know-how available. Hence, while desirability captures the preference of an option by an actor, feasibility is seen to indicate the possibility of implementation of the option.	How does the actor emphasize the overall role (desirability) of this option? 1. Does the actor perceive this option as desirable? 2. Does the actor perceive this option as not desirable? 3. Is the actor having mixed opinions about the option?	1. Positive 2. Negative 3. Mixed	Desirability

(continued on next page)

Table A1 (*continued*)

Feasibility of dimensions which were identified	We mapped the feasibility of the dimensions that were emphasized by the actors. Actors did not emphasize all dimensions for each option. For eg. in the case of some options only two or three out of the six dimensions were mentioned. In contrast to Singh et al., we do not only look for if a dimension was perceived as a barrier but also if the dimension was viewed as an enabler. From the identified dimensions by the actors, it was further classified into positive or negative roles.	Which of the six dimensions did the actor emphasize in discussing the identified option? Within the identified dimensions, did the actor emphasize the dimension to: 1. act as a driver and play a more enabling role? Or 2. rather as a barrier and play a more constraining role in discussing the identified option?	1. Positive 2. Negative	Feasibility

Table A2
Description of codes.

Codes	Description
Adaptation option	Refers to the adaptation measure or action identified by the actor.
Category Sub-codes: – Grey/Physical infrastructure – Green/Natural infrastructure – Institutional changes – Hybrid	Type of adaptation option
Overall desirability (positive/negative)	Indicates if the actor expresses desirability for an adaptation measure (positive) or is not in favour of it (negative)
Feasibility dimensions Sub-codes: – Environmental – Economic – Technological – Institutional – Social – Geophysical	Environmental dimension describes the impact of environmental factors in positively enabling or negatively constraining the identified adaptation option. For eg. the adverse impact of salt water on mangroves would be categorized as a constraining environmental dimension. Economic dimension refers to the role of financial resources, costs, economic vulnerability, economic interests and factors relating to economic development on the adaptation measure. Technological dimension describes the role of technical aspects such as technological knowledge, capacity, infrastructure etc. on the adaptation option. Institutional dimension describes the role of institutional change, governance reforms, measures relating to awareness, capacity building, policy changes etc. in the feasibility of adaptation measures. Social dimension refers to the role of aspects such as social vulnerability, cohesion, cultural and behavioural characteristics, beliefs, values etc. in influencing the feasibility of the adaptation option. Geophysical dimensions refer to the physical, hazard related aspects in defining the potential of the adaptation option.
Role of dimension Sub-codes: – Enabling/positive – Constraining/negative	Each identified dimension was further coded to show if the actor perceives the role of the dimension as an enabling/positive factor or rather as a constraining/negative factor in the feasibility of the identified adaptation option.

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5.2.3 Transition to the third paper

Informed by the key findings of the previous analysis, this paper builds on and further extends the multi-dimensional evaluation framework to link it to the core topic of this thesis – social contracts for adaptation. The major motivation for this paper was to operationalize the concept of social contracts (cf. 5.2.1) in terms of its core pillars – adaptation objectives and roles and responsibilities. In doing so, the study aimed to guide the assessment of social contracts for adaptation and apply it to a real-world case study. The previous two papers provided the conceptual (5.2.1) and empirical (5.2.2) foundations for developing this analysis. The empirical analysis in this paper expands on our previous analysis (5.2.2) that aimed to understand how different actors evaluate different adaptation options for multi-dimensional criteria in terms of desirability and feasibility in the context of flood risk management in Mumbai. This understanding provides crucial insights on the way to assessing and shaping coherent social contracts for adaptation. The third paper builds on this analysis and aims to assess actors' desired adaptation objectives and expected roles and responsibilities for the different adaptation options identified in the previous paper.

5.3 Operationalizing social contracts for adaptation

Citation

Doshi, D. & Garschagen, M. (under review in Regional Environmental Change, under review, re-submitted after receiving minor revisions on 9. July 2024). Actor-specific adaptation objectives shape perceived roles and responsibilities: Lessons from Mumbai's flood risk reduction and general considerations

5.3.1 Summary

Introduction

Conflicts in adaptation priorities and unclear divisions of roles and responsibilities are major barriers to adaptation governance. Yet, these topics of high relevance are heavily under-researched and largely lacking empirical evidence. Previous literature has identified social contracts as a useful lens in adaptation and related fields of sustainability, disaster risk reduction, etc. – however, it remains largely used in a loose and little conceptualized way. This research aims to address that gap. In doing so, this third empirical work builds on the previous analysis and develops a conceptual framework to operationalize social contracts for adaptation. Continuing the qualitative approach of the previous paper, the case study of Mumbai is used to illustrate the usefulness of the framework in real-world settings. Against this background, this paper focuses on two related questions: first, how do different actor groups evaluate the perceived solution space in terms of desired/intended objectives, and for which target actors; second, which roles and responsibilities do they ascribe to which actor(s)? Hence, it operationalizes the concept of social contracts for adaptation into four elements – desired adaptation objectives, target beneficiaries (actors and systems), roles and responsibilities, and ascribed actors.

Methodology

The empirical findings of this paper draw on the same interview data collected and mentioned in the scope of the previous analysis. However, adopting a grounded theory approach and working in hermeneutic circles, the coding and in-depth qualitative content analysis for this paper were done in multiple rounds and informed by the findings of the previous analysis. Additionally, the interpretation of these findings was also triangulated through participant observation at various workshops and stakeholder consultations (in-person and online) that were conducted during the research. In contrast to previous studies on the assessment of adaptation measures, the paper does not impose normative categories of 'adaptation objectives' and 'roles and responsibilities' in the coding. Instead, the analysis was guided by the deductive application of principles of effectiveness and roles and responsibilities discussed in the literature but refined through qualitative coding of the data to also arrive at inductively informed categories.

Findings

The study shows that actors' adaptation objectives and the allocation of roles and responsibilities are embedded in a contested space. The results demonstrate huge mismatches between state and non-state actors on adaptation objectives, target actors, perceived roles and responsibilities, and ascribed actors. On the objectives, we found the largest contestation on efficiency, mostly emphasized by state actors for physical infrastructure measures and opposed by civil society and academic actors for its perceived detrimental impact on other desired objectives such as ecosystem protection, fairness, transformative change, etc. Disparities were also found between actors' perceived beneficiaries – with state actors' beneficiaries perceived to profit the private sector, urban middle class, and elite vis-à-vis civil society and academia prioritizing the interests of vulnerable groups and protection of natural ecosystems. On the roles and responsibilities, the study found the strongest emphasis by actors on the role of planning, in line with the current literature and policy debates. Reflecting the contestation around efficiency through physical infrastructure, the findings showed a stark divide between state and non-state actors on the planning and implementation of such physical infrastructure options. We also found differences in actors' perceptions of who plays a role and who should play a role. Interestingly, state actors perceived themselves to be playing the most important role in flood risk management. Yet, civil society and academic actors, largely ascribed the state with the most responsibility for flood risk management. In total, actors were generally more explicit on the roles and responsibilities (what needs to be done) rather than the ascribed actors (who should do it).

These findings paint a problematic picture. Given that the current approach of flood risk management led by the state is dominated by physical infrastructure options and stands in stark contrast to what civil society and academic actors are calling for – namely major institutional changes in the overall approach to adaptation and a greater prioritization of ecosystem-based options. This is reflected in the wide gaps between the different roles and responsibilities regarding adaptation that actors ascribe to each other and themselves. These findings are important considering that they are shaped by actors' objectives such as securing efficiency, addressing flood hazard intensities, improving fairness, etc. This means that actors currently need to negotiate entirely different and potentially even conflicting underlying priorities on the way to achieving sustainable adaptation.

This research shows that while it is important to understand how different actors evaluate different adaptation options (cf. 5.2), it is not enough and therefore, needs to go beyond and ask for adaptation objectives, target actors, and ascribed roles and responsibilities. This paper makes a conceptual contribution by providing a framework to operationalize the assessment of social

contracts. It advances the multi-dimensional evaluation of adaptation options and provides a link to current scientific debates on adaptation goals and adaptation effectiveness. It makes an empirical contribution by applying the framework to Mumbai which illustrates the importance of laying open the gaps between different actors' perceptions to inform the negotiation of a coherent social contract. Finally, the paper contributes to the ongoing science-policy debates within the global stocktake on the Global Goal on Adaptation by informing the need for qualitative approaches to complement quantitative (e.g. indicator-based) measures to assess the collective progress of global adaptation.

5.3.2 Article

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ORIGINAL ARTICLE

Actor-specific adaptation objectives shape perceived roles and responsibilities: lessons from Mumbai's flood risk reduction and general considerations

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Abstract
Adaptation efforts need to be advanced significantly, involving multiple actors and a diverse portfolio of options. Despite this being well established, there is little understanding of different actors' perceptions of adaptation goals and their associated expectations regarding roles and responsibilities to achieve them. In this analysis, we seek to address this gap by elucidating the diverging viewpoints held by various actor groups concerning adaptation objectives, target beneficiaries, and the distribution of roles and responsibilities for adaptation. Here, we use the case study of flood risk in Mumbai, drawing upon qualitative interview data collected through key informant interviews with diverse stakeholders including state, civil society, and academic actors. Interviews revealed stark disparities between state and non-state actors, in particular on the objective of efficiency, largely emphasized by state actors for physical infrastructure measures. Other contested objectives included ecosystem protection and fairness for vulnerable populations. The findings showed consensus on the importance of planning. Non-state actors heavily debated the lack of planning and implementation of institutional changes and ecosystem-based measures. They called for a stronger role of the state in caretaking and fairness for vulnerable populations, mainly through deeper institutional changes. Overall, the findings point to the urgent need for understanding how actors navigate competing priorities, make trade-offs, and negotiate conflicting viewpoints on the distribution of roles and responsibilities. This paper makes an empirical and conceptual contribution to the debates on "social contracts" for adaptation, offering an operationalization of the concept and application to a real-world example through an actor lens.

Keywords Adaptation objectives · Actor-oriented · Roles and responsibilities · Social contract · Flood risk · Mumbai

Introduction

The urgency and need for advancing adaptation efforts significantly in the face of climate change has been well established—in many respects calling for fundamental transformations in the way societies adapt to climate risks (IPCC 2022; Pelling et al. 2015; Revi et al. 2020; Solecki et al. 2017). Cities, in particular, face huge adaptation challenges, not only due to their high exposure to hazards but also because they are characterized by high path dependency, socio-cultural diversity, competing economic and political interests, and multi-actor constellations with very heterogeneous groups (Adelekan et al. 2022; Dodman et al. 2022). Adaptation to the increasing impacts of climate change requires a mosaic of different adaptation measures and collective efforts involving various societal actors, including the state, private sector, civil society, academia, and citizens (Petzold et al. 2023; Wannewitz and Garschagen 2023). In an ideal setting, actors have a shared understanding of common adaptation goals and visions as well as a clear distribution of roles and responsibilities. However, in reality, multi-actor set-ups often reveal conflicting perspectives on the objectives as well as roles and responsibilities for adaptation. Hence, it is important to understand how actors negotiate diverging viewpoints and contestations around adaptation priorities and the associated roles and responsibilities to achieve them.

Previous research has identified conflicts in adaptation priorities and unclear divisions of roles and

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responsibilities as major barriers to adaptation governance (Garschagen 2016; Juhola 2019; Mees et al. 2019; Nalau et al. 2015; Reckien and Petkova 2019). Related literature in this area has identified the concept of "social contracts" as a useful lens for understanding how societies navigate conflicting visions and clashes in roles and responsibilities for adaptation (Adger et al. 2013; Blackburn and Pelling 2018; Doshi and Garschagen 2023a). In assessing social contracts for adaptation, an urgent but often lacking understanding is of the gaps between actors on their perceived adaptation objectives and expectations of roles and responsibilities for adaptation. While it might not be possible to fully align these gaps between actors' perceived objectives and the mutual allocation of roles and responsibilities, we suggest that making explicit the often tacit and implicit differences to at least identify them and become aware of them would allow actors to mediate the differences and deal with the gaps. Hence, laying open these gaps and engaging with the differences would help inform the process as actors navigate competing priorities, make difficult trade-offs, and ideally align their viewpoints and close these gaps.

Given the need for coherent social contracts for adaptation especially in cities, this paper takes the case study of the coastal megacity Mumbai, not only because it is at high risk of flooding due to its exposure to heavy rainfall but also because of socioeconomic and political drivers that contribute to stark disparities in exposure and vulnerability of different actors. Although Mumbai ranks among the top 10 coastal megacities at risk of flooding and is characterized by high pressure to adapt, research shows that adaptation efforts have been inadequate (IPCC 2019; Singh et al. 2021). Studies have emphasized the need for more fundamental, transformative efforts in adaptation to flood risk in Mumbai and a shift away from the status quo (Adam et al. 2021; Mehta et al. 2021a, b). Whether risk reduction and adaptation is deemed transformative or not strongly depends upon whether it brings about "fundamental change in the system configuration" of risk management and is "putting the core of formerly established system configurations into question," particularly regarding the drivers of risk and vulnerability in existing political economies (Solecki et al. 2017). The temporal and spatial extent of the change can be wide-ranging, depending on the context and system in question (see Solecki et al. (2017) for examples). Complex governance constellations, contested socio-economic and political priorities, striking socio-economic inequalities, and unequal power relations make the process of adaptation challenging (Parthasarathy 2016; Weinstein 2019; Zimmermann et al. 2023).

The empirical analysis in this paper expands on our previous analysis (please see Doshi and Garschagen (2023b)) that sought to understand how different actors evaluate different adaptation options making up their perceived adaptation solution space, in terms of desirability and feasibility. The analysis was guided by a multi-dimensional assessment framework and applied to the context of flood risk management in Mumbai and provided important insights on the way to assessing and shaping coherent social contracts for adaptation. The study presented here builds on this analysis and assesses actors' desired adaptation objectives and expected roles and responsibilities for the different adaptation options identified in the previous analysis (ibid.).This analysis aims to operationalize and assess the core pillars of social contracts for adaptation—adaptation objectives and roles and responsibilities. Please see Doshi and Garschagen (2023a) for the overarching conceptual framing of social contracts for adaptation guiding this analysis.

Against this background, this paper aims to elucidate this issue by addressing two related questions: (1) how do different actor groups evaluate the perceived adaptation solution space in terms of desired/intended objectives and for which target actors, and (2) which roles and responsibilities do they ascribe to which actor(s)? In answering these questions, the paper operationalizes the concept of social contracts into four components: adaptation objectives, target beneficiaries (actors and systems), roles and responsibilities, and ascribed actors. Therefore, this paper aims to contribute to and advance current scientific debates in the following ways: First, to understand social contracts for adaptation by operationalizing the concept and assessing the elements by applying it to a real-world example in the context of flood risk management in Mumbai. Second, to advance the debates on the evaluation of "perceived adaptation solution spaces" by going beyond desirability and feasibility. Third, to contribute to adaptation governance literature, where ambiguity in adaptation priorities and related roles and responsibilities has been identified as a barrier. Finally, it contributes to science-policy debates on the Global Goal on Adaptation, especially informing approaches to understanding actor-oriented perceptions of local adaptation objectives and target actors.

The overall structure of the paper takes the form of six sections. The next section provides the conceptual background and introduces the elements of the conceptual framework guiding this study. The third section gives a brief overview of the case study of Mumbai within the context of its flood risk management drivers and response measures. The fourth section describes the methods employed in this analysis. The fifth section presents and analyses the findings of the research, following the four key elements of this analysis. The final section summarizes the main findings and draws together the empirical and conceptual contributions of the paper with its implications.

Conceptual background

The paper aims to conceptually advance the understanding of social contracts for climate change adaptation, which are crucial for a coherent and transformative approach to adaptation. The study uses a social contracts lens, which is anchored within governance thinking and in which urban risk and adaptation governance are defined as "all modes and institutions by which a city's individuals, social groups and organizations of the state sector and the private domain negotiate their interests, exercise their influence and distribute as well as act upon their responsibilities to manage and reduce urban risk and to enable adaptation across all scales and actors in a city" (Garschagen 2015, p. 608–609). Social contracts have been argued for in the literature as an analytical lens for understanding key issues of adaptation governance (Blackburn and Pelling 2018; Hayward and O'Brien 2010). We define a social contract for climate change adaptation as "a collective arrangement between different actors of a society on the overall vision and goals as well as the mutual distribution of roles and responsibilities to achieve those goals" (Doshi and Garschagen 2023a). In other words, a social contract describes the collective arrangement of what a society wants and the distribution of tasks through which they will be achieved. The definition is inspired, for instance, by Hayward and O'Brien (2010) who asked "what should be secured, for whom and how" (p.211) as well as by Blackburn and Pelling (2018) who highlighted that social contracts are about the contested question of "who" is responsible for "what" in risk governance (p.2). We build on these questions and argue that the "collective" nature of social contracts and the "mutual" distribution of roles and responsibilities emphasize the importance of justice and fair governance while acknowledging that such arrangements require trade-offs that will have to be made between different adaptation goals and visions and trigger negotiations around the distribution of roles and responsibilities. Hence, coherent social contracts for adaptation are understood to be embedded within the boundary concept of risk and adaptation governance.

While the conceptual framing adopted in this paper acknowledges the classical contractarian theory's proposition of the social contract as an outcome of consent (Cress 2006), it suggests a differentiation of two types when applied to the context of adaptation since adaptation often takes place in a socially contested space. A Type 1 social contract describes an arrangement where "actors' visions and perceptions of mutual roles and responsibilities do not align but where actors seek a social contract to precisely mediate these differences" (Doshi and Garschagen 2023a, p.1). This describes the situation in which actors negotiate their potentially diverging goals and visions as well as roles and responsibilities to form a coherent social contract for adaptation. A Type 2 social contract describes an arrangement in which "actors' visions and perceptions on mutual roles and responsibilities align and actors seek a social contract to explicate and formalize this agreement" (ibid.). Each type of social contract may have three dimensions, i.e., the imagined social contract, the practiced social contract, and the legal-institutional social contract (Blackburn and Pelling 2018). The "imagined" dimension describes actors' envisioned goals and expectations of roles and responsibilities. The "practiced" dimension describes the "real-life" goals pursued and the observable distribution of roles and responsibilities (de facto). The "legal-institutional" dimension describes the formally defined goals and visions and legally encoded distribution of roles and responsibilities (de jure) (ibid.) In this paper, we focus on the "imagined" dimension in particular, i.e., the perceived and expected objectives and allocations of roles and responsibilities.

Gaps may exist between the three dimensions, i.e., the practiced, legal-institutional, and the imagined as well as within one dimension, for example, between different envisioned goals and distributions of roles and responsibilities. We acknowledge that while it might not be possible to fully resolve the gaps and contestations, we suggest that making actors' perceptions explicit would at least lay open the gaps and allow actors to engage with these differences and find an arrangement to deal with the gaps (i.e., form a Type 1 social contract) or ideally even inform the process of closing these gaps and aligning the diverging views (i.e., a Type 2 social contract). Hence, by conceptually operationalizing the understanding of social contracts for adaptation into these four elements in this analysis, the paper aims to inform the debate and "formation of at least Type 1 and ideally Type 2 social contracts on climate change adaptation in cities and beyond" (Doshi and Garschagen 2023a). For more details on the conceptualization of social contracts for adaptation, please see Doshi and Garschagen (2023a).

The above definition is operationalized in terms of four key elements that guide the empirical analysis in this study: desired adaptation objectives, target beneficiaries—actors/systems, roles and responsibilities for adaptation, and actors ascribed with roles and responsibilities. These four elements are assessed here in the context of the adaptation options identified and evaluated by actors described in the previous analysis (Doshi and Garschagen 2023b). The conceptual framework below (Fig. 1) provides an overview of how the four elements together with the previous analysis on the multi-dimensional evaluation of adaptation options (Doshi and Garschagen 2023b) contribute to the overarching aim of the study in understanding and assessing social contracts for adaptation.

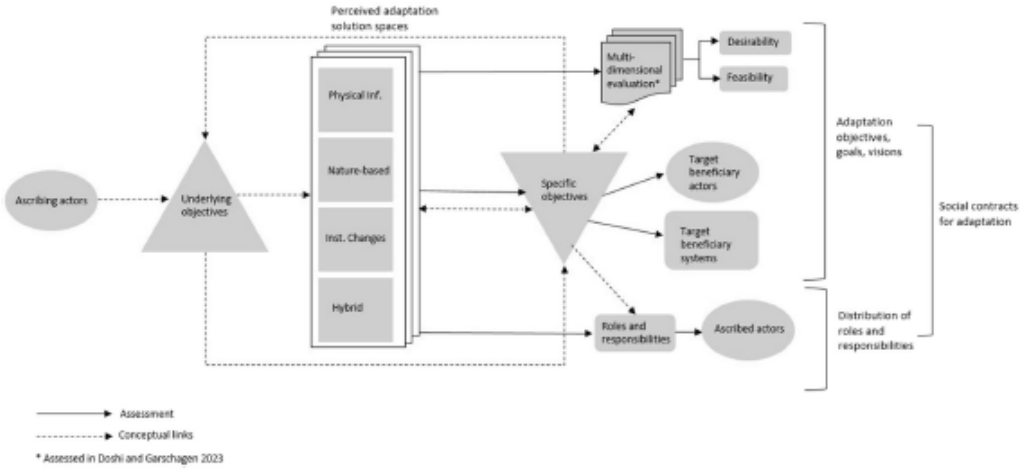

Fig. 1 Conceptual framework guiding the actor-specific assessment of social contracts for adaptation

The adaptation options could be broadly categorized into physical infrastructure, natural infrastructure, institutional changes, and hybrid measures (referring to a combination of one or more of the previous categories). Given the context-specific and "socially constructed" nature of adaptation solution spaces, we adopt an actor lens in this study (Haasnoot et al. 2020). Hence, the above-mentioned four elements are assessed from the perspectives of different actors in the empirical context of flood risk management in Mumbai.

Overall goals and visions for adaptation are operationalized through understanding actors' desired adaptation objectives, or in other words the question "adaptation for what." These objectives are seen to reflect the normative understanding of what actors want to achieve through adaptation or the process of adaptation, acknowledging that the goals of adaptation can be both to "be well-adapted" or to "adapt well" (Downing, T, cited in Tschakert and Dietrich 2010, p.2). Actors' desired adaptation objectives reflect their adaptation needs and priorities, which may stem from political, economic, social, and cultural factors. We differentiate here between two types of objectives: one, actors' underlying objectives that might influence the identification of adaptation options that make up the perceived solution space of an actor in the first place. Second, specific objectives that actors might have for the identified adaptation option. We focus on the specific objectives in this analysis, i.e., the objectives that actors might have for individual different adaptation options. Actors' objectives for adaptation might be influenced by their values, beliefs, and priorities that relate to other development challenges as well. For example, civil society actors working in the environment sector might have different objectives than those working in the humanitarian sector. Similarly, for state actors, competing priorities for urban development, political feasibility, and financial constraints could influence adaptation objectives. Furthermore, objectives can be both process-based, e.g., fairness through an emphasis on procedural justice, or output-based, e.g., efficiency in terms of minimizing costs. Adaptation objectives are closely linked to effectiveness and depending on which objective is pursued, influence how the effectiveness of adaptation options is evaluated and interpreted (Singh et al. 2022). The eleven frames of effectiveness deductively inform our assessment. Please see the "Methods" section and "Results" section for deductively and inductively identified adaptation objectives from the empirical findings.

It has been well established that climate change impacts different actors and systems differently (due to differing exposure and vulnerability) and that different actors and systems have different capacities to adapt to the impacts of climate change (Araos et al. 2021). Closely related to the element of actors' desired adaptation objectives is the question of "adaptation for whom" (equity-related) (Reckien et al. 2023). These questions are operationalized through "target beneficiaries—actors/systems." Here, by "whom" we refer to actors for whom the objectives are intended to benefit rather than counting individual beneficiaries. In order to avoid taxonomical confusion with "for what" (used above for actors' desired adaptation objectives), "for whom" refers to both actors as well as systems that are intended to benefit from the adaptation measures. This could refer to different actors such as the state, citizens, private sector, and academia or systems such as the natural ecosystem.

Previous literature suggests that clearly defined roles and responsibilities for actors are an important prerequisite to delivering effective adaptation (Fünfgeld 2010; Juhola 2019; Garschagen 2016; Mees et al. 2012). While it is important to clarify which adaptation objectives are sought and for whom, it remains equally important to address "what constitutes the fair governance of those adaptive transitions" (Pelling et al. 2015). In other words, the question then becomes, who is ascribed with which roles and responsibilities to achieve those objectives. Roles and responsibilities have been used differently in various studies in the adaptation context and remain fuzzy, e.g., often used interchangeably or without a clear definition (Juhola 2019; Mees et al. 2012; Reckien and Petkova 2019). In the context of this study, roles refer to "an actor's general position or function within a larger social system and in a certain process, here, climate change adaptation." (Petzold et al. 2023) Responsibilities are defined as the "specific tasks and duties that come with roles" (ibid.). In order to structure the assessment of roles and responsibilities, we draw on the categories by Petzold et al. (2023) which identifies seven categories—assessing, awareness raising, planning, financing of measures, implementing, coordinating interaction, and monitoring and evaluation. At the same time, being open to new impulses emerging inductively from the empirical data, we include categories of roles and responsibilities such as capacity building, maintenance, regulation and enforcement, engagement and communication, and "not mentioned" for ambiguous descriptions of roles and responsibilities (see Table 2).

The element "ascribed actor(s)" here refers to the actor or actor constellations that the ascribing actor assigns the identified adaptation role to. Actors may ascribe roles and responsibilities to different actors, ranging from state, private, civil society, citizens and academia, constellations thereof, or even to themselves (self-responsibility). The specific actor or actor groups may vary across different adaptation options, spatial scales, over time, etc., and be influenced by contextual factors such as institutional arrangements of the place, risk perception of the ascribing actor, and own capacities. Given the political and financial implications of adaptation (e.g., who bears the burden of the impacts of climate change in terms of economic losses or health damages, costs of adaptation interventions), actors may often remain ambiguous on the mutual allocation of roles and responsibilities for adaptation to different actors. Unclear distributions of roles and responsibilities have been identified as a major barrier in adaptation governance. Therefore, it is of urgent importance to make explicit and understand actors' expectations of roles and responsibilities for adaptation from different actors or themselves.

Case study

We use the case study of Mumbai, a high-risk coastal megacity in India that ranks among the top 10 coastal megacities with the highest exposure of population and assets to flood risk globally—both in today's as well as in future rankings (Hanson et al. 2011). The city experienced its worst flood in 2005 when 944 mm of rainfall fell within 24 hours (Hallegatte et al. 2010). However, flooding is a regular phenomenon during the city's annual monsoon season (The Guardian 2014). Not only is Mumbai at high risk driven by changes in hazards and exposure but also because it is confronted with high vulnerability (Chatterjee 2010; de Sherbin and Bardy 2016; Weinstein 2019). The city is characterized by stark inequality, with a highly powerful and wealthy small urban elite on the one hand, while on the other hand, over 40% of the city's socio-economically vulnerable population lives in informal settlements, often in flood-prone areas (Census of India 2011). This inequality is reflected in the differences between individuals' exposure and vulnerability as well as adaptive capacities to flooding (Patankar 2015). Besides being characterized by high adaptation pressure, Mumbai being the commercial capital of India receives a lot of attention in political and financial terms—suggesting high adaptive capacity in principle (The Financial Express 2022). However, while Mumbai's flood risk is driven by climate change, it is also strongly influenced by the political economy of urban development in the city, for example, market-driven interests (Adam et al. 2021; Movik et al. 2023; Parthasarathy 2003). Examples of anthropogenic drivers of flood risk in Mumbai include surface soil sealing that resulted in a loss of natural ecosystems and floodplains, inadequate solid waste management, and drainage infrastructure that leads to waterlogging (Gupta 2007; Hallegatte et al. 2010; Pattaroni et al. 2022).

Our previous analysis showed that the current landscape of flood risk management in Mumbai is highly contested—embedded in deep divides between different actors and their perceptions of adaptation solution spaces (Doshi and Garschagen 2023b). State-led formal flood risk management approaches are heavily based on physical infrastructure measures such as the maintenance and upgradation of the stormwater drainage system (BRIMSTOWAD) that acts as the city's central response mechanism to flooding. While this is important in the city's flood risk management, civil society and academic actors strongly emphasize the need for institutional changes in urban governance such as reforms in land use planning that prioritize ecosystem services and policies for affordable and safe housing for vulnerable populations who are often displaced in the implementation of large infrastructure projects. Vulnerable populations are often adapting autonomously, employing

informal measures such as raising floor heights, elevating valuable goods, and building temporary flood barriers at the door entrance. While there is convergence between different actors on the desirability of ecosystem-based measures in principle, such as protection of mangroves, wetlands, and salt pan lands, civil society and academic actors also highlight the major constraining role of political and economic interests in implementing such measures.

Against this background, understanding actors' adaptation objectives and priorities and how they envision achieving them, i.e., the distribution of roles and responsibilities, is of high importance. Most recently, conflicting priorities became visible in the case of the Coastal Road, a highly contested infrastructure project, that was advocated by the state in reducing congestion and acting as a seawall (Movik et al. 2023). However, civil society and citizens perceived it as a project benefitting the urban elite and meeting real estate interests at the cost of harming shoreline ecology and disrupting fishing communities (Mumbai Mirror 2019). Questions of whose voices hold influence are shaped by processes such as political-economic relations and of high relevance in a city like Mumbai where almost half of the population lives in informal settlements and is characterized by heterogeneity and related societal fragmentations along the lines of religion, language, gender, caste, income, migrant status, etc. (Shaban and Aboli 2021).

Contestations in formally defined plans and policy documents, i.e., gaps between the "legal" and "practiced" / "imagined" dimensions of social contracts, can also be seen. Gaps between formally defined objectives in different policy instruments are a challenge—such as the aim to reduce the effects of flooding in Mumbai's Vision 2030 but the absence of demarcating flood-prone areas in the Development Plan 2034 or dilution of the CRZ regulations that intend to protect coastal areas. Gaps and ambiguities in formally defined roles and responsibilities for disaster management have also been questioned, most recently visible during the pandemic (Bhide 2021). Similarly, the division of roles and responsibilities of state and non-state actors, for example, between the core national legislation on disaster management and national urban flood management guidelines, also suggests some mismatches (Chhotray 2014; GoI 2010; Pandey 2016).

Methods

The empirical findings presented in this paper draw on qualitative data collected through 37 semi-structured interviews with key informants and stakeholders across actors from the state (11), civil society (12), and academia (14), working on flood risk management in Mumbai. Key informants were initially identified based on a literature review and then through purposive and snowball sampling. State actors were specifically selected as informants because they form the key decision-makers that drive the dominant paradigm of flood risk management in the city and to understand firsthand their concerns, priorities, challenges, and perceived roles and responsibilities in flood risk management. These included officials, for example, from the city's civic authorities (Municipal Corporation of Greater Mumbai), planning organization (Mumbai Metropolitan Region Development Authority), and departments of the state government of Maharashtra that could provide expertise in relation to planning, legal regulations, infrastructure development, etc. Civil society actors were selected as informants as they can speak to the concerns of some marginalized groups. While they are taken as proxies in this case, it is essential to acknowledge that they might have their own political agendas and biases that are hard to identify. Hence, the voices of the civil society actors, mostly including NGOs working at the local level, cannot be read as representative of "public opinion." For this, it is important to triangulate the findings from this analysis using different methods to capture other groups, for instance, using social listening for large Twitter data (Doshi and Garschagen 2023a), household surveys, participatory observation, etc. Civil society actors interviewed were individuals working across a range of issues, such as environmental justice, social vulnerability in informal settlements, and ecosystem protection, mostly from NGOs working at the local level. Academic actors were selected as informants in particular because they could probably be the closest to innovative and new approaches for adaptation to flood risk and provide an overview of changes from past to current, and directions for the future. Academic actors interviewed were often professors and senior researchers at universities and think tank organizations. While the study could not include perspectives of at-risk communities at this stage due to COVID-19 pandemic–related travel restrictions for fieldwork, in the next step of this research, we aim to triangulate the findings with data collected through a household survey with communities and surveys with small- and medium-sized enterprises that are at risk of flooding. The sampling process could not identify specific private sector actors as key informants (especially looking for larger companies that might play a role through "corporate social responsibility" initiatives); yet, this is acknowledged as a step for future research.

The transcribed interviews were analyzed using in-depth qualitative content analysis (Mayring 2000) and coded following a grounded theory approach with inductive as well as deductive codes in Maxqda (Glaser and Strauss 1967). The findings from individual adaptation-related measures identified by actors are aggregated to broader categories of context-specific adaptation options such as BRIMSTOWAD drainage infrastructure,

ecosystem-based adaptation, and measures targeting improved governance. The multi-dimensional evaluation framework is presented at the broader level of adaptation options (219 in total). These categories of options are further combined into meta-level categories of options—grey/physical infrastructure, green/natural infrastructure, institutional changes, and hybrid. These categories are inspired by the IPCC's Sixth Assessment report (IPCC 2022) but informed by the data.

The interpretations of the findings are also informed by participant observation at various stakeholder consultations conducted in the frame of this research project and the development of the Mumbai Climate Action Plan (MCGM 2022). This paper does not impose normative criteria or understandings of what adaptation objectives should be or for whom. Instead, adopting a grounded theory approach, the analysis is informed by both the deductive application of guiding principles for effectiveness (Singh et al. 2022) and roles and responsibilities (Mees et al. 2012; Petzold et al. 2023) discussed in the literature. But equally importantly, it aims to understand inductively what objectives and roles actors in the Mumbai case emphasize for the different adaptation options that they identified in their perceived adaptation solution space. This allows us to capture context-specific and actor-oriented gaps and contestations. It also allows us a more granular understanding of where gaps lie in local adaptation contexts. Hence, the approach differs from most previous studies that apply only normative criteria identified in the literature to large N studies against which adaptation options are assessed by the researchers. Here, we aim to show how actors assess different adaptation options for objectives they prioritize and for whom. Furthermore, we assess which roles and responsibilities actors identify and ascribe to whom for the different adaptation options.

Results

In this section, we present results from the Mumbai case study to illustrate and explore the conceptual elements introduced in the "Conceptual background" section.

Adaptation objectives

Overall, we observed eight main categories of adaptation objectives (see Table 1). Actors identified two types of objectives—one, as normative goals (e.g., to protect ecosystems) and some emphasizing process-based objectives (e.g., fairness through participatory planning). Despite the overlaps and potential synergies between some of the objectives, given that the specific focus of each objective is sufficiently distinct, we present them separately. It is important to point out that some objectives are not at the same taxonomical level, e.g., reduced risk and transformative change.

In total, across all three actor groups, the strongest emphasis was on ecosystem protection and improved governance. However, we observed large gaps in the extent to which different actors emphasized different objectives, reflecting the diverging priorities of different actor groups. For civil society and academic actors, caretaking, ecosystem protection, fairness, and improved governance accounted for a large majority of their desired objectives. In contrast, the same objectives were emphasized to a much lesser extent by state actors. Overall, non-state actors indicated the strongest desire

Table 1 Overview of adaptation objectives, indicator and relevant adaptation options identified in the analysis

	Type of objective	Indicators identified	Examples of adaptation options
1	Caretaking	Ensuring physical and social safety, livelihood security, improving health and well-being	Improved early warning systems, safe and affordable public housing, and social protection measures
2	Ecosystem protection	Restoring ecological health and services, valuing ecosystem functions, strengthening environmental legislation	Protection of mangroves, creeks, wetlands; rejuvenation of the Mithi river, re-evaluation of land use plans for ecosystem protection
3	Efficiency	Halting capital-intensive projects, shifting away from the profit motive, optimizing resource allocation	Upgrading of the drainage system, investment in large infrastructure projects, optimizing allocation of resources for flood protection infrastructure
4	Fairness	Distributive justice, procedural justice, spatial equity, inter-generational equity	Investment in public transport, participatory planning, inclusive policies for housing
5	Improved governance	Accountability, policy coherence, transparency, strengthened institutions	Increased collaboration between stakeholders, changes in planning norms, broadening skills for risk management
6	Reduced risk	Reduced exposure, reduced vulnerability, addressing increasing hazard intensities	Retrofitting infrastructure, changing building regulations, flood barriers such as dykes
7	Transformative change	Change from a resistant approach, change from a colonial mindset, broaden approach of understanding the problem and solution space, shift from superficial changes to deeper, long-lasting measures	Revision of the bureaucratic view of risk management, open and participatory process for debates on transformation, change in risk perception
8	Not mentioned/Unclear	Where the desired objective was not clear	NA

for transformative change, through suggestions of major institutional changes in the way flood risk is managed and governed. State actors largely prioritized risk reduction primarily by addressing exposure to flood risk, with measures that did not call for fundamental changes or shifts from current approaches to flood risk management. However, we also observed ambiguity or absence of explicit objectives in some cases.

Efficiency was the most common denominator in the contestations between state and non-state actors. State actors argued for efficiency largely through physical infrastructure measures, whereas non-state actors argued against efficiency through physical infrastructure measures because of its focus on increasing profit and achieving short-term impacts at the cost of their desired objectives of ecosystem protection, fairness, caretaking, improved governance, transformative change, and even increasing risk in some cases. One civil society actor succinctly captured the conflict between efficiency and ecosystem protection and said "Mumbai's solution is to allow soak to take place – but the real estate business cannot make money from soak. They can make money only from cement" (R4, a leading activist and founder of a national level NGO). However, justifying the objective of efficiency, one state interviewee emphasized the need to optimize the allocation of limited resources in consideration of India being a developing nation and having other priorities as well. Pointing out the contestation between efficiency and fairness in terms of procedural justice, one civil society actor emphasizes the need to make trade-offs (R25, a leading member of a locally based NGO). The actor suggested that instead of making the Mumbai Climate Action Plan quickly within a few months, state actors should have made it a longer process but ensured that diverging sections of society were consulted and provided a space where contradictory voices could be played out. The emphasis here is on achieving fairness in the process—"and either people agree with it or don't agree with it and then that will be a different process but that means opening yourself up..that means being able to accept that we will have vulnerable points..where people can attack us on some of these solutions.." (R25, a leading member of a locally based NGO).

Ultimately, one academic actor noted "we are working towards a very different goal and I think that is the way development planning in Bombay is happening because certain interests.. and if that is the case" then all adaptation efforts are "just kind of a greenwash" (R29, senior researcher at a major institute). This view of "so-called adaptation projects" such as river beautification or re-development of informal settlements and their relocation as ways to open up "prime land" which were rather geared towards profit-making and maintaining the status quo (R29) was also shared by some other non-state actors. Thereby resulting in the actor's desired objective for transformative change, e.g., through strengthened legislation and planning norms. While most actors emphasize the need for having clear goals and visions, one academic actor also cautions against having vision statements that are "too centered around the aspirations of a very small group of people or one person" and calls for a more collectively informed expression of what the city wants driven by goals and targets as opposed to "catchy statements" (R10, another senior researcher at a major institute). Hence, these findings underline the need in the literature for increased attention to the politics of adaptation and the "geographies of power and agency," i.e., the processes that influence who gets to decide whose desired objectives count, whose voices are heard, and whose oppositions would make a difference (Blackburn and Pelling 2018).

The conflicting views between actors suggest the need to make trade-offs and negotiate competing priorities, discussing questions such as "how do you arrive at a fair and just exchange of land that's needed for public infrastructure projects to the people that are living there?" (R20, assistant professor at an international university) These negotiations bring to the fore important issues of equity such as entitlement and who deserves what—e.g., should slum dwellers get better, affordable, and secure housing, paradigmatic shifts in mindsets of viewing the informal populations as the "other" and viewing them as "encroachers" and not as citizens, and ultimately power structures of whose objectives and for whom matter, despite whether middle-class groups or marginalized communities oppose them. The findings showed that laying out clearly what actors' adaptation objectives are and for whom they are envisioned can inform the discussion on the distribution of roles and responsibilities.

Target beneficiaries—actors and systems

On the question of targeted actors or "for whom" the desired objectives were identified, our findings revealed significant patterns. While target actors such as people, state, and civil society formed the largest share, a significant share of desired objectives were envisioned for entities such as ecosystems and the city of Mumbai in general. In many cases, actors remained ambiguous or did not identify specific target actors. While some actors used "people" as a homogeneous category, other interviewees specified distinct sub-categories such as citizens, vulnerable people (e.g., migrants, slum dwellers, fishing communities), and rich people (e.g., middle classes, elites). Most actors wanted improved governance mainly for the state, people, and civil society organizations. The desired objectives of fairness and caretaking broadly showed consensus among ascribing actors and were almost unanimously envisioned for people, particularly vulnerable populations. Similarly, ecosystem protection was unsurprisingly emphasized for different ecosystems such as creeks, wetlands, and mangroves. In comparison, efficiency, transformative change, and reduced risk revealed more contested and unclear patterns. For increased efficiency, while half the cases were associated with the state, the remaining cases were ambiguous. Target actors for

transformative change have been mixed, with no clear pattern emerging among diverse actors. Finally, the desired objective of reduced risk (in terms of hazard intensity and exposure) was the most unclear in terms of target actors. This ambiguity could be due to multiple reasons, e.g., the political nature of the question (as it indicates potentially who benefits and who bears the burdens of adaptation) or it remains contested.

Many civil society and academic actors noted the conflict between the state and private sector actors whose interests around real estate, profit-making, large infrastructure projects, etc. are largely intended to benefit the state, real estate groups, and elite or upper middle-class residents of Mumbai. On the other hand, they raised concerns on the question of entitlement and who deserves what. They argued for caretaking and fairness for vulnerable populations by providing affordable housing, social safety nets, and preventing livelihood disruptions, fair resettlement and relocation, etc. To that, some civil society actors pushed for recognizing slum dwellers as citizens and not "encroachers" or "encroachments," as is the common vocabulary referring to informal settlements or slum dwellers in practice as well as formal policy documents. In this regard, some civil society actors noted the deeper change required in this regard of dismissing the limits of imagination, viewing the informal as the "other," questioning the role of the city and its fundamental configurations, and constructing compassion and respect for people living in urban slums. Hence, while these debates revealed the contestations around target beneficiaries, they also underlined the importance of making explicit not just the desired objectives but also the associated beneficiaries.

Roles and responsibilities

In total, we identified eleven major categories of roles and responsibilities from the data. While we found significant overlaps with categories identified by Petzold et al. (2023), our inductive coding also yielded three additional categories—capacity building, regulation and enforcement, and engagement and communication. Table 2 provides an overview of the different roles, responsibilities (types of activities), and examples of adaptation options in the context of which they were expressed.

We observed significant differences between different ascribing actors in terms of the roles that they emphasized for the different adaptation options they identified. Academic actors strongly emphasized planning within their perceived solution space, followed by assessing, implementation, and ambiguity. Among all actor groups, academia placed the strongest emphasis on awareness raising, capacity building, and monitoring and evaluation for adaptation to flood risk in Mumbai. Civil society actors strongly emphasized

Table 2 Overview of roles, responsibilities, and relevant adaptation options identified in the analysis

	Categories of roles and responsibilities	Types of activities	Examples of adaptation options
1	Assessing	Research; impact assessments; knowledge generation	Climate stress tests for infrastructure projects; research on "sponge city" measures; social impact assessments for projects
2	Awareness raising	Action-oriented research; engagement with other stakeholders;	Early warning systems; sensitization of citizens and state actors on climate change
3	Capacity building*	Training; engaging with stakeholders	Training people in following early warnings
4	Maintenance*	Repair, rejuvenation, cleaning	Revival of drainage system; lake cleaning
5	Planning	Policy-making; coordination; collaboration	Social security support for migrants; provide affordable housing; land use planning regulations to prioritize urban green spaces
6	Monitoring and Evaluation	Controlling; evaluation	Re-evaluation of land use plans, monitoring of drainage cleaning
7	Regulation and Enforcement*	Stronger enforcement of existing regulations; changes in planning norms	Legal protection for the urban poor; declaration of low lying flood plain areas as no development zones
8	Engagement and communication*	consulting; influencing; pushing governance	Creating a dialogue between civil society and city planners; encouraging youth participation in politics
9	Implementation	Execution; construction; setting up	Waste management system for informal settlements; (stop) implementation of retention walls along drainage lines
10	Financing and Investment	Allocation; budgeting	More investment in disaster preparedness; more investment in mangrove protection
11	Not mentioned*	Ambiguous description of roles and responsibility; not mentioned or unclear	NA

*Categories that emerged inductively from the data

planning, similar to academic actors, followed by an emphasis on implementation. In comparison to other actors, civil society actors placed the strongest emphasis on regulation and enforcement. Both actor groups placed stronger emphasis on the importance of engagement and communication, financing, and maintenance in comparison to state actors. Many state actors placed significant emphasis on implementation and planning for adaptation. In contrast to academic and civil society actors, we found a weak prioritization of awareness raising, capacity building, engagement and communication, financing, and maintenance by state actors.

Overall, we found the strongest emphasis and consensus among all ascribing actors on the role of planning for adaptation in the context of flood risk management in Mumbai. Under planning, examples of typical responsibilities that actors mentioned were policy-making, coordination, collaboration, etc., and referred to options such as social security schemes for migrants, providing affordable housing for slum dwellers, changing land use planning regulations to prioritize urban green spaces, etc. The role of implementation was the most contested by different actors. For physical infrastructure options, civil society and academic actors expressed their strong disagreement on the implementation of physical measures such as the Coastal Road and drainage retention walls which they viewed as ineffective in reducing flood risk, with even the potential for increasing exposure and vulnerability of fishing communities living along the coast and informal settlement along drainage lines. Non-state actors heavily debated the implementation of institutional changes and ecosystem-based measures, highlighting challenges confronting land use planning and governance reforms that are deeply entrenched in the political economy of Mumbai, such as path dependencies, commercial interests, and political relations. Civil society and academic actors identified the broadest range of roles and responsibilities for institutional adaptation measures, such as assessments for designing "climate stress-tests" for infrastructure projects, awareness raising for sensitizing citizens to early warning systems, planning and monitoring, and evaluation of land use reforms. Finally, we identified a certain degree of ambiguity for roles and responsibilities in the case of roughly 10% of the perceived solution space. The contestations and gaps in ascribed roles and responsibilities can be linked back to actors' objectives (both underlying and specific).

Ascribed actors

Our findings reveal significant patterns in terms of which actors were ascribed to take on what role. Overall, state actors were the most frequently mentioned actor group perceived as responsible for different roles in adaptation to flood risk in Mumbai—especially planning, implementation, financing, and regulation and enforcement. Not only were they ascribed roles and responsibilities by other actor groups, i.e., civil society and academia, but they also perceived themselves being the main actor that plays a role in adaptation to flood risk in Mumbai. The difference, however, lies in the type of adaptation options that the actor groups identified and ascribed to the state. Civil society and academic actors mainly assigned different roles and responsibilities for nature-based options and institutional changes to state actors. They frequently assigned the city authority (Municipal Corporation of Greater Mumbai) with the primary responsibility as many drivers and impacts of flooding related to civic infrastructure and services such as drainage, waste management, and water supply. Some academic and civil society actors emphasized the role of planning departments to be of central importance and especially the need to understand the heterogeneity between planning for a "basti" (slum) vs a housing society. They called for a stronger role of the state in planning, financing, and caretaking for vulnerable populations and not expecting or leaving it to the private sector under their CSR mandate or some NGOs to give money. Some academic actors questioned the larger overall role of the state in looking out for the vulnerable and called for investigations into why the role of the state has shrunk under the influence of World Bank policies and other international aid programs. State actors themselves self-ascribed roles and responsibilities such as planning, implementation, and financing for physical infrastructure measures. One state actor viewed the role of the state, especially the MCGM as the only and main actor that plays a role in flood risk management in Mumbai (R8, leading official in the municipal authority). The wide gaps in roles and responsibilities ascribed to the state originate largely due to the different perceived adaptation solution spaces.

The roles and responsibilities associated most frequently with civil society actors included engagement and communication, and planning. Actors overall called for a stronger role by citizens in planning, and civic engagement in the form of holding state actors accountable beyond expressing their frustration on social media and awareness raising. Some civil society actors attribute the weak role of citizens, especially of the middle-class and elite groups to a sense of apathy, lack of clear instructions for citizens, lack of belongingness or ownership of the city, etc. However, civil society actors also share their concern for the most vulnerable people who are just struggling to survive in the city, to "ensure that your daily bread is in place" (R3, a journalist and writer at a think tank organization) which leads people to get used to problems and continue working despite hardships, often referred to as the resilient "Mumbai spirit" (R1, a leader in a locally based NGO). The findings revealed little mention of the role of private sector in adaptation, suggesting that actors did not perceive the private sector to have major responsibilities in adaptation. These findings underline the importance of a clear distribution of roles and responsibilities for adaptation.

The role of academia was largely seen in raising awareness and conducting and supporting risk assessments, monitoring and evaluation, consulting state actors, and supporting coordination, collaboration, and capacity building in planning processes. Finally, actors also acknowledged the challenge of ambiguity and clarity in who is responsible for what in flood risk governance. One civil society actor for example raised concerns about assigning the private sector to take responsibility for maintaining a stretch of the Mithi in the Bandra Kurla Complex under the CSR mandate but acknowledges the problem of formally defined ownership—"…but who do it? And when to do it and how to execute it? This is the question. Because the ownership of the river itself is not clear in the country" (R13, assistant professor at a major institute). Another source of ambiguity lies in the gaps between what roles and responsibilities may be formally defined and assigned to actors and what happens in practice on the ground. One civil society actor suggests that the ambiguity may even remain "you keep that grey area, the ambiguity, and everyone is taking advantage of that ambiguity, you know, because it's lying there and everyone wants to just push the ball in each other's court" (R13, assistant professor at a major institute).

Discussion and conclusion

The findings presented in this paper help to improve the understanding of actor-oriented adaptation objectives and roles and responsibilities for adaptation in the context of urban flood risk in Mumbai. The study shows that adaptation objectives and the distribution of roles and responsibilities to achieve them are negotiated in a contested space. This research is embedded in the context of the emerging need to understand how societies will achieve a coherent social contract for adaptation—by agreeing not only on which goals and visions different actors want for adaptation but also how they want to get there—i.e., who is expected to play which roles and responsibilities.

The findings demonstrate that there are currently huge mismatches in adaptation objectives, target actors, perceived roles and responsibilities, and ascribed actors between state actors on the one hand and civil society and academia on the other. The findings suggest that these contestations are rooted in the political economy of the overall development of Mumbai. Confirming previous literature, a major driver shaping urban development in Mumbai is asymmetric power relations that influence land use planning and policy-making (Pattaroni et al. 2022). Past studies show that the heavy pressure on land uses in the city results from competing demands due to vested interests of powerful real estate lobbies, housing shortages for almost half of the population that lives in informal settlements, protection of ecosystems such as mangroves and wetlands, and infrastructure projects to meet the civic needs of the city (e.g., the diversion of the Mithi River for the construction of the airport) (Chattaraj 2019; Doshi 2019; Mehta et al. 2021a; Weinstein 2019). State actors prioritized physical infrastructure measures such as drainage retention walls and underground holding tanks to ensure efficiency and reduce physical exposure to flooding. Although not explicitly mentioned by state actors, civil society and academia indicate that these measures are largely intended to benefit middle-class and elite residents of the city and closely connected real estate builders and contractors. This prioritization of "grey" infrastructure measures is in line with the current literature that shows how such measures dominate and constitute the traditional approach to flood risk management (Jones et al. 2012), yet received concerns for potentially giving a false sense of security, requiring significant investments and potentially having drastic impacts, for example, in the case of a collapse of dams or dykes (Apine and Stojanovic 2024; Depietri and McPhearson 2017). Empirical data also suggests that a major challenge in urban development for planners and policy-makers is dealing with path dependencies of past developments, such as land reclamation projects and built-up areas that generate high runoff and are "locked in" due to the difficulty of easily undoing "hard" infrastructure developments. At the same time, it is certain that state-led top-down structural adaptation is required for a city like Mumbai. Nevertheless, the findings show that it should not be the only one and rather complemented with bottom-up soft adaptation.

In contrast to state actors, civil society and academic actors laid a stronger emphasis on ecosystem-based options such as mangrove protection and institutional changes such as changes in land use planning regulations for achieving the objectives of ecosystem protection, caretaking, fairness, and improved governance. These objectives are intended for ecosystems and vulnerable groups such as slum settlements, migrants, and fishing communities. The findings emphasize the urgent need for two things in designing effective adaptation portfolios for achieving coherent social contracts for adaptation—first, arriving at the "right mix" of measures (Doshi and Garschagen 2023b; Jongman 2018). Second, the "right mix" will vary across space and time and differ for different actors—because of this, understanding and negotiating different and potentially divergent actor perspectives will be crucial. These aspects pose a central challenge for risk and adaptation governance (Molenveld et al. 2020).

In total, across all adaptation options, planning was the most strongly emphasized role by all actors. The biggest contestation on roles and responsibilities for adaptation was identified around the planning and implementation of physical infrastructure measures and institutional changes. The findings reflect the divide between civil society and academic actors on the hand, who call on state actors to stop planning and implementation of such physical infrastructure options and strongly

modify land use planning norms, for example. On the other hand, state actors recognized themselves (self-responsibility) as playing the most important role in flood risk management through their roles in planning, implementation, and financing of physical infrastructure measures. However, while formal planning is an important and intrinsic part of adaptation governance, informal arrangements will also play a crucial role in Mumbai, given that almost half of the city's population lives in informal settlements (Chattaraj 2019; Satterthwaite 2011). In terms of ascribed actors, the largest expectation was from the state actors. Civil society and academia were ascribed different roles such as awareness raising, engagement and communication, assessing, and capacity building to themselves and citizens. While actors were more explicit on what needed to be done (roles and responsibilities), there was more ambiguity on the question of who should do it, especially noted in planning, assessing, regulation, and enforcement.

These findings are problematic given that the current approach of formal state-led flood risk management dominated by physical infrastructure measures is currently highly contested and in stark contrast to what civil society and academic actors are calling for—namely major institutional changes and ecosystem-based adaptation (Chouhan et al. 2016; EPW 2015; Movik et al. 2023). The gap between the non-state actors' envisioned objectives and their enforcement could be explained by a strong gradient in power relations, for example, through differences in the capacity to envisage and enact, the lack of power to make decisions, determine financial priorities and allocations, and lack of opportunities and spaces for meaningful participation and voicing concerns in formal planning processes. This is important considering that actors currently need to negotiate entirely different, and potentially even conflicting underlying priorities of securing efficiency, reducing physical exposure, and addressing flood hazard intensities that are aimed at benefitting actor groups such as the state, private sector, and wealthier citizens vis-à-vis caretaking, ecosystem protection, fairness, and improved governance that are targeted towards protecting the environment and vulnerable groups. This implies the need for a more explicit negotiation of roles and responsibilities between state, civil society, and academia in achieving the different adaptation priorities. Finally, findings from Mumbai demonstrated the challenge of ambiguity in terms of unclear desired objectives that lead to unclear roles and responsibilities.

An important consideration for future research here could be to triangulate the findings with a review of grey literature including planning and policy documents to map out the gap between the "imagined" social contracts and "legal-institutional" social contracts. The next step would be to identify the concrete opportunities that exist or could be created to enhance the effective engagement of non-state actors in major decision-making processes for flood risk management in Mumbai. In line with previous literature, the findings suggest the need for critical attention to power relations in societal structures that will potentially influence which goals, objectives, and visions get translated into practice.

While the study could identify and make explicit the gaps and divergences between different viewpoints, in order to understand if and how actors navigate and negotiate these gaps, a deeper analysis of the reasons for these gaps and divergences is required. The findings suggest some strong hypotheses to explore further in future research through further empirical testing. Furthermore, the empirical data also points to the persistence of gaps (e.g., path dependencies in planning), leading to reinforcement of the status quo and, in some respects, a reproduction of risk. Hence, the findings raise critical questions for further research—what explains the existence of these gaps and divergences in the first place? In this regard, it would be worthwhile to explore the temporal dimension of these gaps and whether they are a matter of time lag or persistence. In case of the latter, what are the potential reasons for the observed inertia in the city's flood risk management approach that actors perceive as a reinforcement of the status quo, and why might it be difficult to overcome? One senior academic actor from a leading think tank organization highlighted the challenge of building capacity and awareness for climate change concerns when working with state institutions largely comprised of engineers who have undergone very different training wherein their first response is always of defense and a focus on extreme events. The finding suggests that mainstreaming climate change concerns in formal institutions will require intensive engagement and identifying appropriate tools for supporting decision-making. This identified challenge resonates with Hewitt (1983), who critiques the technocratic style of work, including the tendency to focus on "controlling" disasters and neglect the everyday nature of relations that shape risks and disaster events. Hence, the findings caution against an easy interpretation of the task of forming and negotiating coherent social contracts for adaptation, which will be difficult to achieve without deeper institutional changes and enforcement of different objectives.

On a conceptual level, these findings suggest that making explicit actors' desired adaptation objectives and allocations of roles and responsibilities would at least lay open the gaps and potentially enable actors to engage with these differences to allow the process of forming a Type 1 social contract where actors may find an arrangement to deal with their gaps and diverging viewpoints on both objectives and roles and responsibilities. Ideally, however, actors would find a way to resolve these gaps and potentially close them to shape a Type 2 social contract. The question, therefore, becomes: how do/could actors negotiate and resolve those gaps to close them and move towards a Type 2 social contract? The combination of these findings from the case study analysis provides some support for the conceptual premise that aligning actors' desired

adaptation objectives and for whom they are envisioned could be a potential entry point and step in the direction of shaping a Type 2 social contract. This is because having shared objectives essentially shifts the negotiation of roles and responsibilities from the question "who does (or should do) what" to "how do (or should) we get there." In other words, actors no longer negotiate competing or conflicting goals; instead, they negotiate the distribution of roles and responsibilities towards the shared goal(s). However, despite shared objectives, the gaps and contestations in roles and responsibilities might still remain, but the negotiation is a different one. For example, one civil society actor underlined the value of being on the same page in bringing about transformative change with the state, which may still be "messy" and involve debate between diverging viewpoints but still expedite the process by almost 50–60% (R25, a leading member of a locally based NGO). Findings from Mumbai support the premise that actors may have entirely different ideas of what needs to be done and who is responsible for what and in which intensity, but having an aligned shared objective will change the direction of that negotiation.

The study makes a conceptual and empirical contribution to advance the understanding of social contracts for adaptation by adding actor perceptions on the questions of desired adaptation objectives, target actors, and roles and responsibilities in real-world settings. The paper argues and contributes towards making explicit actors' adaptation objectives and expectations around roles and responsibilities in order to identify where potential gaps and divergences lie. Unclear roles and responsibilities have been identified as a barrier to adaptation governance (Garschagen 2016; Juhola 2019; Mees et al. 2012). At the same time, the study argues that although clearly defined roles and responsibilities might not directly translate to a coordinated response, it is an important step on the way to achieving coordinated and comprehensive adaptation planning and implementation. Furthermore, clarity of roles and responsibilities strengthens accountability. This is seen as a necessary but not sufficient step towards shaping coherent social contracts for adaptation.

As a next step, further analysis is required to understand the reasons for those gaps and divergences, why they might persist and are difficult to overcome, and finally, how this gulf might be addressed. The findings from this analysis suggest that aligning objectives could be an important directional turn in negotiating coherent social contracts for adaptation. On the way to overcoming gaps and aligning divergences in objectives, roles, and responsibilities for adaptation, it is important to acknowledge the inherent challenges of social relations that contour the capacity of any particular actor to envision and enact adaptation objectives for themselves or others and power relations that play an important role in influencing whose priorities are translated to practice. Furthermore, the findings also call for a deeper exploration of factors that shape the attribution of responsibility—both to themselves (such as imagined capacity, felt agency) as well as to others. Hence, the study argues for coherent social contracts for adaptation that push for a more inclusive risk governance approach "which collects the voices of all stakeholders and mediates their interests as well as their potential contributions and responsibilities" (Garschagen 2016, p.48).

The findings from this study and future research recommendations are further highlighted by their timeliness and relevance to global debates at the science-policy interface, in view of the seventh assessment cycle of the IPCC and its planned special report on cities and climate change. The assessment aims to inform policy processes on the Global Stocktake (GST) under the Paris Agreement (UNFCCC 2015). In particular, the analysis aims to contribute to debates on the Global Goal on Adaptation, especially in the design of a Monitoring, Evaluation and Learning (MEL) system for assessing collective progress on adaptation (UNFCCC 2015). The divergences in adaptation objectives question the feasibility of a universal definition of adaptation success or effectiveness, concurring with Dilling et al. (2019) and calls for critical attention to power relations and dynamics that shape the definition and enforcement of adaptation objectives of different actors. The GST also reviews the adequacy and progress in adaptation finance. The conceptual discussion in this analysis suggests that which objectives are pursued, for whom, and who is ascribed with what roles and responsibilities ultimately has implications on what gets financed and how—thereby significantly influencing the progress on adaptation.

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Declarations

Conflict of interest The authors declare no competing interests.

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6. DISCUSSION

The following chapter synthesizes and reflects on the key contributions of this dissertation to scientific debates on understanding and assessing social contracts for adaptation to climate change - in (and at the interfaces of) empirical, methodological, and conceptual realms (Figure 12). The chapter is structured in the following way: First, the key scientific contributions of the study are presented (6.1 to 6.5) that emerged from the findings in response to the five research questions guiding this dissertation (cf. 1.3). Second, the transferability of the study is discussed in empirical, methodological, and conceptual terms (6.6). Subsequently, resulting from this discussion, section 6.7 presents future research needs and recommendations for adaptation research that emerge from this dissertation. Finally, the chapter concludes with the relevance and contributions of the study at the science-policy interface (6.8).

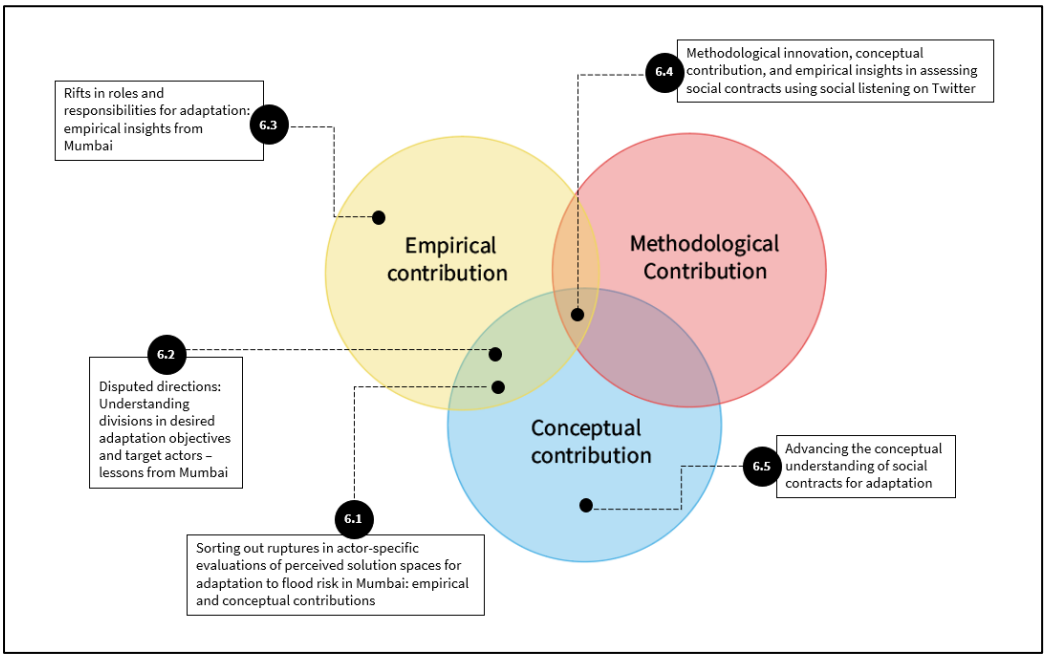

Figure 12: Mapping the main scientific contributions across conceptual, methodological, and empirical realms

6.1. Sorting out ruptures in actor-specific evaluations of perceived solution spaces for adaptation to flood risk in Mumbai: empirical and conceptual contributions

Adaptation to the increasing impacts of climate change will require societies to design context-specific portfolios of risk management options. In doing so, it is important to understand how different actors evaluate their 'perceived' solution spaces for adaptation (RQ 2). The following section discusses four key contributions that emerged at the interface of empirical and conceptual realms through this study from the findings in response to RQ 2.

6.1.1 Actor-specific lens in the evaluation of perceived solution spaces for adaptation

First, given the 'socially constructed' characteristic of solution spaces for adaptation and the contested landscape of flood risk management in Mumbai (cf. 4.2) the empirical findings clearly demonstrate the value of including actor perceptions and comparing the multi-dimensional evaluations of adaptation solution spaces by different actors. The study goes a step beyond current

multi-dimensional assessments of adaptation options (cf. 2.2.3) that largely focus on individual options and how they are assessed in the literature by including actor perspectives and applying them to real-world settings.

The empirical findings revealed a distinct divide between state and non-state actors on the perceived desirability and feasibility of physical infrastructure measures (see in detail 5.2), illustrating the importance of actor-specific evaluations of adaptation solution spaces. The dominance of such measures in state actors' perceived solution space and overall positive evaluation in terms of desirability is unsurprising given their establishment in policy and planning documents and implementation. Yet, their dominance remains problematic. Despite the growing critique in the current adaptation literature on the ineffectiveness and challenges of physical infrastructure measures (Depietri & McPhearson, 2017; Scott et al., 2020), the empirical data clearly shows that the predominant framing of formal, state-led adaptation to flood risk in Mumbai continues to rely on technical, hard infrastructure approaches and thereby, in contrast to the calls in the scientific literature on adaptation for alternative and mixed approaches for risk management portfolios (Eriksen et al., 2021; Le, 2020). Furthermore, the emphasis on physical infrastructure measures suggests that flood risk management is guided by an explicitly stronger focus on addressing the flood 'hazard' and 'exposure' components of risk, as opposed to vulnerability (cf. 5.2). While this finding is not surprising, this disproportionate focus on hazard and exposure and neglect of vulnerability stands in grave contrast to the claims of vulnerability literature and critique of the 'dominant view' (cf. 2.1), which calls for addressing the drivers of vulnerability and shifting away from technocratic approaches of risk reduction.

The findings from non-state actors' evaluations of perceived solution spaces are, in contrast to those of state actors, in line with the growing literature that emphasizes the limitations of physical infrastructure measures, in Mumbai and other contexts. The findings enrich the current debate on adaptation to flood risk in Mumbai in two key respects: First, by identifying nuances of the critique, such as the varying intensity of disagreement and desirability among the different non-state actors. On the one hand, some non-state actors perceived many of these mega "so-called adaptation projects" to tend to increase – rather than reduce – the risk of flooding and become maladaptive in some cases, which is in line with previous studies (Kamath & Tiwari, 2022). On the other hand, the less critical perspective showed that some non-state actors acknowledge the role of physical infrastructure measures in flood risk management yet challenge the nearly exclusive reliance on such measures or how they are implemented on the ground. Second, the empirical findings highlight the importance of capturing different actor perspectives, even within the same actor group and even if they are on the same side of the contestation. A recent starkly contested project, the Coastal Road, showed how different non-state actors were protesting the project – but for different reasons. While the scientific literature focused on the protests by the Koli fisherfolk along with some supporting civil society organizations (Movik et al., 2023), media reports also showed how middle-class residents in the neighbourhood and some other environmental NGOs protested primarily for different reasons such as ecological destruction, restricted access to the coastline for leisure activities, construction noise, and pollution (Kirtane, 2019; Mumbai Mirror, 2019). Empirical data from one interview suggested that the dispute around the Coastal Road was "between the haves and the haves" wherein the Koli fisherfolk were just used in the argument (R22, a senior urban planning expert). In favour of the project, while the state actors' arguments in public discourse for the Coastal Road cited reasons

of connectivity, reducing time and distance of commutes, and even its function as a seawall, interview data from some non-state actors suggest that it is driven by strong real estate and middle-class groups. Hence, this stark disparity between the state and non-state actors on the very question of what qualified as an adaptation option underlines the importance of comparing and contrasting actor perspectives in evaluating adaptation solution spaces, which has been largely missing in the empirical literature on adaptation to flood risk in Mumbai (cf. 4.2).

In the multi-dimensional evaluation of physical infrastructure options, state actors perceived financial resources (under economic dimensions) as a constraining factor influencing the feasibility of such measures, for example, citing the challenge of prioritizing limited resources when there are diverse competing priorities for a developing country like India, with flood risk not being the only one (R35, leading official in the municipal authority). This view starkly contrasts many non-state actors' evaluations who perceived financial resources as much less of a constraint, citing examples of expensive large infrastructure projects such as the Coastal Road that reflect different financial priorities and not a lack of adequate financial resources (R20, assistant professor). Interview data suggests that state actors' views on the financial constraints might be linked to two perceptions of flooding: one, a disproportionate focus on extreme flood events and their perceived lack of financial resources to address such events, and two, a quite disaster-centric view, of flooding as a "four to five days problem" that needs to be dealt with and hence, affects their prioritization, raising the question "how much money to spend for this?" (R35, leading official in the municipal authority). Hence, the empirical analysis contributes to the current debates on understanding the diverging role of feasibility dimensions for different actors.

In stark contrast to state actors' evaluation of their perceived solution space for adaptation and emphasis on physical infrastructure measures, both civil society and academic actors emphasized institutional changes and the role of institutional dimensions in the evaluation of their perceived solution space for adaptation. This reflects a strong alignment of non-state actors' perceptions with the calls in the scientific literature on the importance of institutional changes for adaptation to climate change, including in urban contexts (Ajibade et al., 2016; Chu, 2016; Patterson & Huitema, 2019; A. Taylor, 2016). Empirical findings on institutional changes and the pivotal role of institutional dimensions have been presented in detail in Chapter 5.2. The rich empirical insights from Mumbai add to the wealth of case study work in current literature (Ampaire et al., 2017; Huntjens, 2021; Liu & Fan, 2023) that have contributed to the limitation raised in the scientific literature – "Institutions and institutional change are mentioned often but rarely specified in discussions of climate adaptation" (Dovers & Hezri, 2010, p.212). Even further, the empirical evidence has shown that it is not only important to provide a "detailed discussion" of the institutional changes (ibid.) but also examine how different actors perceive and evaluate such measures for their feasibility and desirability.

Overall, the empirical data shows that there is a strong call by non-state actors for more transformative, fundamental changes in Mumbai's approach to managing flood risk. The emphasis on deep institutional changes that make up the biggest share of their perceived solution spaces for adaptation stands in contrast to state actors' views. What the actor-oriented lens clearly revealed is a clear divergence between the state and non-state actors who are largely envisioning two entirely different directions of where Mumbai's risk management paradigm needs to be headed. Even in the few cases where state actors called for transformational change, the approach heavily relies on

physical infrastructure measures, e.g. retrofitting of existing infrastructure. The findings underline two key aspects for designing effective portfolios of risk management options: one, to find the "right mix" of adaptation options that comprise the solution space designed for a specific context (Jongman, 2018). Two, given the temporal and spatially dynamic nature of the solution space, this "right mix" will vary across space, time, and for different actors (e.g., changing political leadership with different priorities). Hence, the empirical findings agree with, for instance, Solecki et al., (2017) on the urgent need to empirically understand how transitions across risk management regimes can be enabled and would further raise the question of how such diverging viewpoints on the envisioned directions of risk management regimes are negotiated and (if they are) reconciled.

6.1.2 Distinguishing desirability from feasibility in multi-dimensional evaluations

Second, the conceptual distinction between feasibility and desirability proved to be very useful and important in gaining sharper insights into actors' perspectives on 'what is desirable' vs 'what is possible'. Without an actor-specific lens, it would not have been possible to separate the notion of desirability from feasibility, which have so far been integrated into the notion of feasibility under 'social acceptance' (Singh et al., 2020). The findings from Mumbai suggested a clear discrepancy between the perceived high desirability of natural infrastructure options in principle (and consensus among all actor groups) on the one hand, yet their perceived low feasibility (primarily from non-state actors) on the other. For example, despite acknowledging the desirability and need for Mumbai to restore its ecosystems and act as a buffer against flooding, one academic actor pointed out that a fundamental challenge is that "Mumbai's solution is to allow soak to take place – but the real estate business cannot make money from soak. They can make money only from cement" (R4, a leading activist and founder of a national level NGO), thereby noting the constraining role of institutional dimensions in the feasibility of ecosystem protection.

Another example from Mumbai that illustrates the distinction between desirability and feasibility is the issue of resettlement. Interview data and participant observation suggests that while resettlement of vulnerable populations away from flood-prone areas is desirable in principle, repeated temporary resettlement was viewed negatively. One academic actor added that even if permanent rehabilitation is an option, social acceptance should be considered (R16, associate professor). Slum clearance and evictions to allow for infrastructure or real estate projects are heavily contested, not only in the literature but also often reported in the media (Bardhan et al., 2015; Doshi, 2013; Jha, 2020; Sharma et al., 2020; The Free Press Journal, 2024; The Wire, 2019). This tension is clearly visible in ongoing debates around the resettlement of Dharavi, considered Asia's largest slum. The Dharavi Redevelopment Project Pvt Ltd (DRPPL) is to be undertaken in a public-private partnership between the Government of Maharashtra and the Adani Group and would lead to the resettlement of over one million people including many cottage industries, making it one of the largest urban resettlement projects globally (Lewis, 2024). Hence, the empirical evidence from Mumbai highlights the need for a more nuanced evaluation of desirability and a revision of the definition of feasibility (to distinguish between desirability and feasibility) for a more coherent and actionable evaluation of adaptation options, confirming previous studies (Döhlen Wedin, 2024; Lemieux & Scott, 2011).

6.1.3 Feedback interactions between different options

Third, the findings suggest the need for future research to consider interactions and feedback between different options – in particular how to manage trade-offs that will need to be made in view of constraining factors such as financial resources, time, and capacities. The findings suggest that the increasing challenge of dealing with multiple hazards such as heat stress and flooding, call for a multi-hazard multi-dimensional evaluation of adaptation solution spaces that recognize the trade-offs and potential synergies that actors might need to consider in their evaluations. Illustrating the negative feedback effects of some options, some academic actors raised caution against measures taken to protect ecosystems (e.g. lake cleaning, mangrove clean-ups) by some civil society actors, despite being highlighted in social media campaigns.[3] They were concerned because it might shift attention away from larger governance reforms needed to prevent pollution, waste dumping, and destruction of natural ecosystems in the first place. In other words, some options were seen to shift the focus away from other, more fundamental changes or measures that might be required. Another problematic line of argumentation revealed on Twitter around the protection of natural ecosystems is the blaming of the marginalized, informal settlements along drainage lines for polluting the river and drainage lines. This is in line with previous studies that show how such arguments have been used in Mumbai and other Indian cities to undertake 'slum clearance' as a measure for improving the environment. These efforts are often driven by the joint interests of state, middle-class and slum residents in the aspiration of improved living conditions (Doshi, 2019; Doshi & Ranganathan, 2017; Zérah, 2007). Bringing the empirical findings together with the claims in the literature points to the challenge of making trade-offs between different options at the nexus of environmental protection, housing needs and aspirations of middle-class residents, slum evictions, and profit motives of real estate developers and state actors.

In methodological terms, there is a need to extend evaluations of adaptation solution spaces beyond single options to entire risk management portfolios and capture the feedback between different options. For example, an agent-based model could be used to examine the interactions between different options of a specific portfolio of measures. Further, such a model could incorporate temporal and spatial changes, going beyond current assessments that largely capture a static snapshot of multi-dimensional evaluations. Given the dynamic nature of such assessments, modelling would allow to incorporate and analyze changes over space and time.

6.1.4 Temporal changes in multi-dimensional evaluations

Fourth, the empirical research has underscored the importance of capturing the temporal dimension of such a multi-dimensional evaluation of perceived adaptation solution spaces, aligning with Singh et al. (2020). The temporal dimension presents challenges in both respects – in terms of past as well as future trends. In terms of past trends, triangulation of interview data with participant observation at workshops suggests the difficult challenge for state actors to deal with deep path dependency and lock-in effects created through physical infrastructure measures built in the past, also raised in the current literature on flood risk management (Wesselink et al., 2015). For example, interview data suggests that in some cases, despite becoming aware of the maladaptive effects of such measures, the path dependencies triggered by the huge financial investments already made or

[3] These findings alert attention to the growing need for understanding the role of middle-class environmental activism in Mumbai, in India, and elsewhere and their influence on shaping the adaptation solution space (Mawdsley, 2004; Zimmer & Cornea, 2016).

the cost of 'undoing' these measures play a disincentivizing role. A deeper exploration of how actors in Mumbai deal with such difficult path dependencies of the past, especially in view of the expected increasing impacts of climate change in the future, is currently the focus of a manuscript under preparation (Garschagen et al., in prep) and aims to contribute to the limited conceptual and empirical literature on path dependencies in the context of adaptation to flood risks (Seebauer et al., 2023). Looking into the future, the uncertainty of the time element in terms of how soon/quickly certain shifts in hazard trends will take place and in turn, how much time is required for implementing the different adaptation options (e.g. setting up a new social security system and constructing a dam have different timelines) has been discussed in the literature on the speed of adaptation (Berrang-Ford et al., 2021). Hence, both past and future trends need to be considered in the multi-dimensional evaluation of perceived solution spaces for adaptation.

Hence, the above findings from Mumbai contribute not only to the current conceptual and empirical literature on the multi-dimensional evaluation of perceived solution spaces for adaptation but also suggest the need for future research to consider actor perspectives, distinguish desirability and feasibility, capture interactions and trade-offs, and incorporate temporal changes.

The following two sub-sections discuss and synthesize the key empirical findings of this study in terms of actors' desired adaptation objectives and target actors (6.2) and perceived distributions of roles and responsibilities for adaptation (6.3) in response to RQ 3 and RQ 4, respectively. The data from Mumbai showed striking mismatches and gaps in both respects on two levels – between different actors and between the three realms of social contracts (imagined, practiced, and legal-institutional).

6.2 Disputed directions: Understanding divisions in desired adaptation objectives and target actors – lessons from Mumbai

This study argued that societies, especially in cities, will need to act collectively to adapt to the inevitable impacts of climate change and require strong and ideally coherent social contracts for adaptation to climate change where different actors align on the overall vision and goals of adaptation and the distribution of roles and responsibilities to climate change. Noting the context-specific and contested nature of adaptation, the study aimed to understand different actors' desired adaptation objectives and target actors in relation to specific measures (RQ 3). This sub-section synthesizes the key findings in response to RQ 3 and contributes to the interface of empirical and conceptual literature on social contracts for adaptation by highlighting the importance of adaptation objectives in overcoming gaps in social contracts and the rarely examined link between adaptation objectives and roles and responsibilities.

The study concurs with Dilling et al. (2019) on the questionable value of a universal definition of adaptation success, given that adaptation is context-specific, shaped by local perspectives, priorities and of critical importance, embedded power dynamics that shape whose priorities and voices matter. Current literature has shown the lack of consideration of adaptation goals in planning documents (Goonesekera & Olazabal, 2022), indicating that policies are far from connecting actions to goals and thereby hindering efforts to measure effective adaptation. Hence, the findings contribute to current empirical and conceptual literature by capturing actor- and context-specific desired adaptation objectives and target actors.

6.2.1 Contestations in desired adaptation objectives and target actors between state and non-state actors

Despite the claims for aligned, mutually agreed, and defined adaptation goals and visions in the current conceptual literature on adaptation, the empirical findings showed strikingly different adaptation objectives between state and non-state actors, emerging from contrasting perspectives on their evaluations of perceived solution spaces for adaptation. Interview data suggests that efficiency was the most common denominator in the contestations, where state actors primarily argued for efficiency through physical infrastructure approaches (cf 6.1.1) but non-state actors contradicted these claims because they believed such measures to be focused on increasing profit and addressing short-term impacts. These perceived objectives were at odds with non-state actors' desired objectives of ecosystem protection, fairness, caretaking, and improved governance, among others. For example, highlighting the difference between the objectives of achieving efficiency and fairness, a civil society actor pointed out that the Mumbai Climate Action Plan should have been a longer process instead of making it quickly within a few months (R25, a leading member of a locally based NGO). Emphasizing the importance of including divergent voices from various sections of society and providing a space for genuine public participation and contradictory opinions to be heard, the findings align with similar arguments raised in the media (Wagh & Indorewala, 2022).

The clear mismatch between actors' perceived adaptation goals became evident, for example, one observation from an interviewee shared - "we are working towards a very different goal, and I think that is the way development planning in Bombay is happening because certain interests ... and if that is the case" then all adaptation efforts are "just kind of a greenwash" (R29, senior researcher at a major institute). In line with previous literature that calls for critical scrutiny of power structures in society, empirical data showed how one actor cautioned against catchy vision statements that are often centered around the aspirations of a small group of people (R10, another senior researcher at a major institute). Instead, a few non-state actors call for a collectively informed expression of what the city wants. Hence, the empirical findings from Mumbai respond to the current calls in the scientific literature to understand context-specific adaptation goals and go further to show the importance of contrasting actor-specific desired adaptation objectives towards forming a collectively shared vision and goals for adaptation (Olazabal et al., 2024).

Closely related to the above is the important question – adaptation for whom? This referred to for whom the desired adaptation objectives were intended. This question and the empirical findings from Mumbai are of high relevance to a city where almost half the population lives in slums, the politics and land use planning run by commercial and market-driven interests, heterogeneity and related societal fragmentations exist along the lines of religion, language, gender, caste, income, migrant status, etc. (Shaban & Aboli, 2021). The findings clearly showed diverse and diverging viewpoints between state and non-state actors on target actors and systems, varying levels of specificity (e.g. broader categories such as the government or people to specific groups such as migrants and fisherfolk), and a significant share of ambiguity (almost a quarter). The data from Mumbai speaks to calls in the literature for understanding "urban adaptation imaginaries" (cf. 2.3.2), that would provide a crucial basis for shaping coherent social contracts for adaptation. While the study is in line with Reckien et al. (2023) in mapping the question 'adaptation for whom,' it suggests going a step further by adding the questions 'adaptation for what' and 'from whose perspective'. Hence, the empirical findings contribute to the current literature by arguing for clarifying not only

what constitutes effective adaptation, but also for whom and suggests that ambiguity in clearly defining in whose interests adaptation is intended or being pursued leads to contestations, hindering effective adaptation (Blackburn & Pelling, 2018; Reckien et al., 2023; Singh et al., 2022).

6.2.2 Gaps in desired adaptation objectives between imagined, practiced, and legal-institutional realms of social contracts

The conceptual framing of distinguishing social contracts into three realms – the imagined, practiced, and legal-institutional (Blackburn & Pelling, 2018) (cf. 2.3.2) proved to be very useful in laying open and identifying the gaps in actors' perceived adaptation objectives, roles, and responsibilities. Results from Mumbai suggest that actors perceived gaps in four key realms: first, between desired adaptation objectives and their translation in practice (imagined and practiced); second, between what they envisioned and the objectives and priorities they perceived to be currently encoded and institutionalized (imagined and legal); third, between the objectives they perceived to be practiced and what is stated in formal terms (practiced and legal) and finally, between different envisioned objectives (different imagined). On the gap between the legal and practiced dimension, interview data showed non-state actors' critical view on the MCAP and their perception of the plan and its "template of typical solutions" as a "lip service" that lacks context-specificity and concrete targets (R16, associate professor). This finding confirms the observation by (Kamath & Tiwari, 2022) who argue along similar lines and find an "ambivalence––of stated protection without any intention to implement it" in the governance of flood risk in Mumbai. The empirical evidence also pointed to large gaps between different imagined or envisioned adaptation objectives. Using social listening approaches, Twitter data revealed contradictory viewpoints on the question of protection of vulnerable populations living in informal settlements. Debating such issues brought to the fore important questions on which adaptation objectives should be pursued and for whom, e.g. should slum dwellers get better, affordable, and secure housing. However, contradictory perspectives showed deep rifts in mindsets, such as strong views of the vulnerable, informal populations as the "other", encroachers" and who should "not expect everything for free" (Doshi & Garschagen, 2023a). This contestation is in line with previous literature that highlights the conflicts in the city, for example, between the protection of green spaces and slum dwellers who are often viewed as "freeloading encroachers" (S. Doshi & Ranganathan, 2017; Zérah, 2007).

These empirical insights highlight the disputed directions towards which adaptation to flood risk in Mumbai is or should be headed. Using an actor-specific and social contracts lens, the findings suggest that aligning actors' adaptation objectives at both levels – between actor groups and closing the gaps between imagined, practiced and legal-institutional realms will be essential in shaping coherent social contracts for adaptation. Aligning diverging or conflicting objectives can be very challenging – especially for ambiguous cases where desired objectives might be very hard to capture due to their implicit, tacit, and political nature. For example, the empirical findings suggest that trying to reconcile conflicting and competing priorities will require trade-offs and dealing with difficult questions such as "how do you arrive at a fair and just exchange of land that's needed for public infrastructure projects to the people that are living there?" (R20, associate professor). However, what the findings show is that before coming to the negotiation of the distribution of roles and responsibilities, it is important to first align adaptation objectives and for whom they are intended. Hence, although aligning desired objectives can prove to be very challenging, the empirical findings show that they are important and a prerequisite to debating roles and

responsibilities for adaptation. The findings (cf. 5.3), therefore, establish the importance of the little-examined conceptual link between adaptation objectives and roles and responsibilities, namely how actor-specific adaptation objectives shape perceived roles and responsibilities.

6.3 Rifts in roles and responsibilities for adaptation: empirical insights from Mumbai

Previous literature has shown that ambiguous or conflicting roles and responsibilities are major barriers to adaptation governance (cf. 2.1.5). A clear distribution of roles and responsibilities is a crucial requirement for achieving coherent social contracts for adaptation (Doshi & Garschagen, 2023a; Petzold et al., 2023). However, the empirical evidence from Mumbai showed major rifts in the distribution of roles and responsibilities for adaptation on two levels: between actors and between the three realms of social contracts, i.e. the imagined, practiced, and legal-institutional. This section draws on the empirical findings in response to RQ 4 based on data from semi-structured interviews, social listening on Twitter, and participant observations.

The following sub-section discusses the empirical findings in view of the rifts between different actors in perceived roles and responsibilities for flood risk management.

6.3.1 Rifts in roles and responsibilities ascribed to state actors

Overall, the largest expectations on roles and responsibilities for flood risk management in Mumbai were directed toward the state, mainly by non-state actors, including individuals, civil society, and academia. Interview data suggested that state actors perceived themselves to be responsible, in one case even identifying the city's civic body (MCGM) as the main and only actor that plays a role in flood risk management (R8, senior official in the municipal authority). Twitter data revealed opposition parties holding state actors accountable for their role in flood risk management, primarily the stormwater drainage authority for drainage cleaning. However, contrasting the perspectives of non-state actors, the data suggested major contestations and rifts in the roles and responsibilities expected of or ascribed to the state actors. These gaps became most evident in two key areas:

First, the main divergence between state and non-state actors' perceptions on the roles and responsibilities of state actors in flood risk management was found to be on the type of adaptation measures that they expected or envisioned. This finding relates to the discrepancy between state and non-state actors' perceived solution spaces for adaptation and their evaluation. For example, while both state and non-state actors agreed on the responsibility of state actors for planning and implementation, they envisioned these for entirely different measures and approaches. Further, non-state actors emphasized a stronger role of the state for responsibilities of financing, maintenance, and regulation and enforcement, in contrast to the weak emphasis on the same by state actors. While these findings are in line with Petzold et al. (2023), where state actors are primarily identified with the task of planning in the literature, the empirical findings suggest that going a step further in asking for adaptation options and using an actor lens (ascribing actor) revealed significant mismatches. In addition to the importance of formal planning in adaptation governance, informal arrangements indicated in the literature will also be crucial for a city like Mumbai ('jugaad' governance[4]), where nearly half of the city lives in informal settlements (Chattaraj, 2019; De Wit, 2016).

[4] The popular local term 'jugaad' in Hindi refers to "makeshift adaptations, workarounds and improvisations under constraints"(Chattaraj, 2019)

The findings clearly showed strong contestations on the protection of the most vulnerable living in informal housing in flood-prone areas. Two starkly opposite views were revealed on Twitter. On the one hand, individuals demanded protection for vulnerable populations, e.g., relocation to safer areas (including a petition to the High Court). On the other hand, individuals blamed the vulnerable, perceived them as illegal dwellers or 'encroachments,' and argued against the use of their taxpayers' money for such rehabilitation and resettlement measures, in line with previous studies that note elite and middle-class interests in favour of slum clearance (see 4.2.2). In contrast to Twitter data, the interview data showed alignment between non-state actors who expected the state to protect the vulnerable and perceived the role of the state to have become weaker with the advent of international aid organization and their policies. In other words, what the empirical findings suggest is that it is not only about if and how the state should protect the vulnerable (according to non-state actors and some individuals) but also if the vulnerable should be protected (i.e. instead being blamed and demanded to be removed). The findings suggest the need to go beyond current literature on the distribution of roles and responsibilities (cf. 2.1.5) and take one step back to understand how roles and responsibilities are contested in the first place. Hence, what this finding brings out is that the crucial question of 'if and who is responsible for protecting the vulnerable' is situated at a nexus of varying conflicting interests.

Second, strong differences were found not only between different ascribing and ascribed actor groups, but also within members of the same actor group (for example, the diverging perspective of individuals on the role of the state for protecting the vulnerable mentioned above). Gaps in 'who was responsible' (ascribed actor) even within different state actors was revealed by the empirical findings – for example, different municipal authorities (e.g. storm water management, disaster management, housing), state (Maharashtra) vs city or district level authorities and the metropolitan authority. This finding on the discrepancy and related ambiguity in the distribution of roles and responsibilities of the state is in line with the fragmentation of responsibility between different institutions discussed by (Parthasarathy, 2016a), for example, resulting from the spatial break-up of ecosystems according to the administrative jurisdiction.

6.3.2 Rifts in roles and responsibilities ascribed to non-state actors

Roles and responsibilities to non-state actors were largely self-ascribed, albeit with few exceptions from state actors. Despite the calls in the literature on the involvement of non-state actors in adaptation efforts (Revi et al., 2014) empirical findings from Mumbai confirm broader patterns in the literature which found that the majority of state-led adaptation initiatives in cities focused on the involvement of the public sector and only a limited involvement of non-state actors, i.e. citizens and the private sector (Hegger et al., 2017; Klein et al., 2018). Furthermore, in alignment with the literature that notes the limited involvement of citizens in defining the problem of adaptation and its solution space, empirical findings confirm this observation and show that non-state actors emphasize the need for greater involvement of civil society, academia, and individuals in adaptation planning through meaningful public participation, engagement, and communication (Sarzynski, 2015). Academic actors particularly identified their role in awareness raising and engagement, whereas civil society in implementation and coordination or facilitation. While the role of the private sector in influencing urban planning and development was mentioned, their role in adaptation efforts was hardly emphasized. This finding confirms calls in the literature for a stronger role and increased involvement of the private sector in adaptation efforts (Klein et al., 2018; Schneider, 2014).

In contrast to findings from the interview data, social listening allowed for a novel empirical perspective in adaptation debates by revealing self-responsibility ascribed by and to individuals, primarily "middle classes and other 'dominant castes and classes'" (Doshi & Garschagen, 2023a). Two diverging views could be identified. On the one hand, individuals called out to fellow citizens to play a more active role in the debate on flood risk management in Mumbai through stronger political participation and overall, blamed citizens for lacking agency. Interview data suggested reasons of apathy, a lack of belongingness, and a feeling of ownership as reasons for the weak engagement of citizens in public debates to hold state actors accountable. Yet, the data also showed that individuals did also participate actively in the public debate on Twitter: by raising their voices for protection and support for the vulnerable populations living in informal settlements and questioning the responsibility for them. On the other hand, the opposite was also observed in which individuals asked others to stop complaining about the floods in Mumbai and sympathize with the public sector due to the intensity of the rainfall. While this contrasts with the finding above that calls on individuals to play a more active role, it confirms that middle-class individuals have been participating in debates and holding the state actors accountable for their role in flood risk management. Hence, the findings signal a contested role of the middle class that departs from earlier observations that noted the lack of attention of the middle class to flood risk management debates and concerns of the vulnerable (Parthasarathy, 2009).

In contrast to Mehta et al. (2019) where perspectives on uncertainties of climate change in Mumbai of the middle and upper-middle class residents are merged with residents living in informal settlements under perspectives "from below", the empirical findings of this study suggest the usefulness and importance of understanding the perspectives of the middle class separately on adaptation debates. This finding contributes a novel insight to the empirical literature on the perceived roles and responsibilities of the growing middle class in flood risk management, in Mumbai and beyond. With more than half of the world's population expected to be a part of the global middle class by 2030, with the most rapid and largest growth taking place in the global urban South (Kharas, 2017) understanding and clarifying the roles and responsibilities expected of the aspirational middle class has a powerful influence in shaping not only social and political but also economic trajectories by forming the biggest consumer class in society will be of prime importance to adaptation debates, yet currently heavily under-researched. Further, the empirical insights from Mumbai, being the commercial capital of India, are of high relevance given that the largest contribution to middle-class growth is expected to come from India and China (Caballero & Fengler, 2023; Short & Martínez, 2020). Methodologically, social listening and its potential to capture the views of the middle class in adaptation debates can be explored further by exploring other social media platforms e.g. TikTok, Instagram, WhatsApp, and Facebook, depending on country, context, age group, topic of interest, etc. (discussed further in 6.6).

6.3.3 Gaps in roles and responsibilities between imagined, practiced and legally defined realms of social contracts

Using the conceptual distinction of social contracts into the three realms (imagined, practiced and legal-institutional), the empirical analysis revealed surprisingly large gaps between the roles and responsibilities that actors imagined or envisioned, what they observed to be practiced in reality (de facto) and what they perceived as formally defined or institutionalized (de jure). For example, overhauling entire departments responsible for flood risk management, building regulations that do

not allow construction in low-lying areas, or meaningful public participation that goes beyond 'tick the box' exercises on paper. The findings highlight the importance of improving our hitherto very patchy theoretical and empirical understanding of imagined social contracts in particular – and their relation to practiced and legal social contracts (Blackburn & Pelling, 2018). Ambiguity in roles and responsibilities was noted in both respects – between actors and between realms of social contracts. Hence, the findings reiterate the importance of defining clear roles and responsibilities for adaptation, the lack of which has been identified as a major barrier in adaptation governance (cf. 2.1.5). The study contributes to the current literature by laying open and identifying gaps, mismatches, and rifts in actors' perceptions on the distribution of roles and responsibilities.

While the empirical findings provided rich details and insights on expected responsibilities associated with different adaptation measures, the study notes that actors' expected roles for adaptation could not be clearly concluded. To provide a richer understanding of the roles that actors expect of others and themselves, a deeper investigation of underlying rationales by asking why actors ascribe certain responsibilities to specific actors is required. Understanding of rationales and the mode of governance through which actors are involved is important because of their impact on adaptation outcomes. For example, if the rationale for shifting responsibilities to the private sector is a limitation of resources, adaptation could become more efficient. Further empirical research is needed to enlighten the conceptually fuzzy understanding and distinction between roles and responsibilities, which are often used interchangeably in the current adaptation literature (cf. 2.1.5).

In summary, the study contributes to the current empirical and theoretical literature on social contracts for adaptation by showing actors' expectations of roles and responsibilities for adaptation. The study confirms the usefulness of an actor–specific and social contracts lens in identifying gaps and mismatches between (and within) actor groups as well as imagined, practiced, and legal-institutional social contracts. By laying open these gaps and rifts in expected roles and responsibilities, the study contributes to informing the discussion toward negotiating coherent social contracts for adaptation. The study acknowledges that clearly defined roles and responsibilities do not automatically imply their implementation in practice or in coordinated action. Nevertheless, the study argues that laying open gaps and ambiguities in roles and responsibilities is a necessary but not sufficient step for negotiating coherent social contracts for adaptation. As a next step of the analysis, a deeper investigation of not only why the gaps exist but also how such a gulf might persist and be difficult to overcome is required (further discussed in 6.7).

6.4 Methodological innovation, conceptual contribution, and empirical insights in assessing social contracts using social listening on Twitter

The most innovative contribution of this research has been through the development of social listening using large Twitter data to assess social contracts for adaptation in urban contexts and beyond and forming the first publication of this dissertation (see 5.1). In doing so, the study responds to RQ 5. The importance of social media platforms and networks have been recognized as important arenas for the exchange of opinions, ideals, and information, also known as the "digital equivalent of a town square" where "netizens" take discussions to digital spaces, especially during the Covid-19 pandemic that constrained such discussions in physical public spaces (Rosier, 2020). Social media spaces have gained widespread and tremendous influence in the Internet era (Ilieva & McPhearson, 2018). However, the use of big data, including social media data, in climate change adaptation

research has been viewed as an "opportunity gap waiting to be filled" (Ford et al., 2016, p.10732) and heavily underutilized (cf. 3.4.1). In response to this research gap and in view of the above characteristics of social media platforms, Twitter was carefully selected (cf. 3.4.1) and proved to be an apt platform to assess social contracts in this study. While the selection and development of social listening had partly developed out of the necessity of the pandemic-related travel restrictions on fieldwork, the data collection and analysis proved to be particularly useful in capturing a rich debate that had shifted to the digital space in view of the then ongoing pandemic in 2021. Social listening enabled the study to expand the empirical space from the observed, 'offline' world to the digital world and analyze the debates among 'netizens' in shaping social contracts for climate change adaptation in Mumbai.

While there has been a wealth of studies that have used social media data in climate change research, employing quantitative methods such as topic modelling, geospatial analysis, quantitative sentiment analysis, social network analysis, machine learning, and semantic analysis, the use of qualitative and mixed-methods approaches is emerging to capture nuanced insights from big data (Andreotta et al., 2019). This study contributes to the growing body of literature exploring mixed-methods approaches in using social media data as a novel source for adaptation research. The combination of quantitative methods to filter the dataset, identify broader trends in dominant debates, and gauge socio-economic profiles of participants using innovative proxies combined with in-depth qualitative analysis of tweets proved to be highly relevant and useful. Manual qualitative coding in this analysis allowed the capture of important, small, and nuanced yet rich context-specific insights from big data to capture "contextual complexity" and go beyond identifying broader trends, topics, and relationships in the data set (Ford et al., 2016).

Social listening approaches have been argued in the literature to be more "ecologically valid" in comparison to traditional methods of data collection such as surveys or interviews (Andreotta et al., 2019) due to the data emerging from "real-world social environments" without any influence of the researcher in eliciting the data (p.1767). In consideration of my positionality (cf 3.2), social listening proved to be insightful in generating empirical insights that might not have emerged in the context of expert interviews or household surveys. The value of this opportunity afforded by social listening particularly contributed to the analysis of sentiments, reflected below.

The qualitative analysis of sentiments[5], revealed through social listening allowed for a novel contribution at the interface of methodological, conceptual, and empirical realms, thereby providing a way to capture and understand gaps in social contracts in the case of flood risk management in Mumbai. In contrast to the often-employed quantitative techniques of sentiment analysis in social media research, such as NLP, AI-assisted machine learning and Large Language Models that focus on large-scale systematic mapping and most often yield positive, negative or neutral categories of sentiments, the qualitative analysis of sentiments in this study makes a significant contribution to big data analytics by analyzing tacit expectations and emotions (Müller-Hansen et al., 2023; Repke et al., 2024). Manual qualitative coding of sentiments allowed to capture sentiments such as frustration, disappointment, lack of hope etc. through text (often including multi-language and context-specific vocabulary) but also enveloped in sarcasm and humour for example through

[5] Sentiments in the context of this study are defined as "feelings or emotions associated with viewpoints or opinions shared in a Tweet".

memes, GIFs and emoticons. Such nuanced insights would not have been possible to capture through algorithm-generated mapping of sentiments. The unsolicited nature of data collection, as mentioned above, also potentially limited my influence and role as a researcher in triggering certain sentiments and thereby capturing more 'honest' emotions.

Beyond the qualitative analysis, the empirical case of Mumbai allowed to reveal a range of sentiments due to the generally open debates in line with the country's ideals of "Freedom of Speech" and the use of online spaces to voice opinions (Government of India, 1950; The Economist, 2024b). While this might be more challenging to capture in other empirical cases, due to constraining factors such as political freedom of speech, internet data regulations, or cultural aspects, studies have also shown how the opposite could be true, e.g. the case of Iranian online vs offline privacy (Aeini et al., 2023) suggests despite a conservative culture and high offline privacy, online privacy in Iranian social media is relatively unalerted.

Finally, at the conceptual level, sentiments revealed through social listening helped to identify gaps in social contracts – especially between different imagined social contracts but also between the imagined, practiced, and legal dimensions of social contracts. Hence, in view of the challenge noted by Blackburn & Pelling (2018) of methodologically capturing imagined social contracts and the gaps between them, sentiments identified through social listening proved to be a novel approach.

A concern in using social listening and social media data more broadly is the representativeness of the sample, raised in Chapter 3 (cf. 3.4.1). In other words, the use of social listening in this study might raise the question, of how representative the sample of the participants on Twitter might be in comparison to that of Mumbai? In the geography of digital space, also on Twitter in this case, users cannot be regarded as representative of the population of Mumbai. Given the limitation of georeferenced data from Twitter, it was not possible to identify the exact share of Tweets that were tweeted from outside Mumbai or even India. However, Tweets from user accounts of think tanks, international academic experts, civil society organizations, international and national media houses, and national disaster management agencies showed that influential contributions to the virtual debate were also made from beyond the geographical boundaries of Mumbai. Moreover, in India and elsewhere, representation of populations in social media data is inherently linked to internet access and digital literacy and varies across demographics and geographies – also known as the "digital divide" (Dargin et al., 2021). Despite limited metadata on the socio-demographic information of the users who participated in the Twitter debate, the study devised an innovative proxy to gauge the socio-economic profiles of participants in the Twitter debate in India. The proxy used the language of the Tweet and the device through which the Tweet was tweeted.

The findings suggested that the picture that more educated and affluent urban middle classes and elites participated over-proportionally in the dominant debates holds when looking at the language and type of device used for tweeting. Using social listening on Twitter revealed perspectives of the middle classes and elite sections of society on flood risk management in Mumbai, thereby contributing to a hitherto understudied empirical perspective in adaptation debates (see above in 6.3.2). In view of the importance of the middle classes, which have a disproportionate influence in shaping public debate on topics of social, environmental, economic, and political interest through their strong role in the media, politics, bureaucracy, state authorities, academia, and legal system

(Mawdsley, 2004), methods such as social listening could provide an innovative approach to capture their perspectives on adaptation challenges.

Furthermore, it remains important to acknowledge that while social listening did not allow to capture the perspectives of vulnerable populations directly, whose participation might have been restricted due to different challenges, e.g., digital literacy, internet access, and affordability, several actors, including individuals, media, and civil society voiced concerns of vulnerable populations. Moreover, this profile might change in the future, especially considering that less than half a decade ago when most of the one billion plus population was analog, now one in two Indians is a "netizen" (The Economist, 2024b). Hence, a future step of this research involves triangulation with household survey data in Mumbai to capture the direct perspectives of vulnerable households affected by flooding, which could not be conducted during this study due to the pandemic.

While the data and the methods allowed to lay open the gaps between different actors and dimensions of social contracts, some black boxes remain and could not be captured sufficiently. First, the gaps between the imagined and the practiced and legal dimensions of social contracts from state actors were only possible to capture in a limited way, potentially due to the lack of openness and political sensitivity of the issues. Second, despite the long period over which the data was collected (four months of the monsoon season), longitudinal assessments would be important to capture dynamics such as changes over time, e.g. after the current elections in India, the influence of new infrastructure projects such as the Coastal Road, or other extreme events such as the ongoing heatwaves in India.

In view of the challenges of social media data above, as well as being cognizant of the algorithms that play a significant role in shaping social media platforms and interactions, e.g., the creation of echo chambers and reinforcing certain beliefs or opinions, the study does not claim to provide a complete assessment of social contracts through social listening. Instead, it explored the development of social listening as a method that revealed tacit and implicit expectations and the gaps between them, thereby capturing an important segment of the societal debate on flood risk management in Mumbai taking place in a digital space. However, it was important to perform both method and data triangulation, as done through semi-structured key informant interviews and participant observation. Opportunities and challenges of transferring social listening approaches will be discussed in detail in section 6.6.2.

6.5 Advancing the conceptual understanding of social contracts for adaptation

The study argues that adaptation, especially in cities, often takes place in a socially contested space, characterized by multi-actor constellations with potentially diverging viewpoints between different actors. Against this background, it is argued that the first and foremost step is to lay open and make explicit the often implicit and tacit perceptions of different actors on adaptation goals and visions as well as roles and responsibilities. The main conceptual contribution of this study has focused on this step. These gaps manifested in two ways – between different actors and within and between the imagined social contracts and their relation to the legal and practiced social contracts. In response to the identified research gap on a lack of sufficient conceptualization of social contracts for adaptation to guide its operationalization and empirical assessments (cf 1.2), the study raised RQ 1. The following section synthesizes the key conceptual contributions that emerged in combination with the empirical analysis.

A key conceptual contribution of this study is the provision of a working definition of social contracts for adaptation (cf 2.4.1). The definition thereby addresses a critical gap in the previous literature wherein social contracts for adaptation have been loosely invoked, often as a metaphor, but without a concrete definition that could guide analysis (cf 1.2). In contrast to current definitions of social contracts in related fields and the one adopted by Blackburn & Pelling (2018) in the context of adaptation, the definition suggested here aimed to bring together the debates on adaptation goals and visions (raised in previous literature on social contracts for adaptation, cf 2.3.1) with that on the distribution of roles and responsibilities – the latter being the more commonly referred to notion under the concept of social contracts (Adger et al., 2013a; Blackburn & Pelling, 2018; Christoplos et al., 2017). The definition allowed to provide a solid basis for operationalizing the concept of social contracts for adaptation into its four key elements to guide assessments. Such a holistic lens enabled through the definition may, therefore, support decision-making in policy debates on adaptation governance where it can potentially inform negotiations of transitions across risk management regimes that might be confronted by competing visions and diverging perceptions on the allocation of roles and responsibilities, particularly in multi-actor constellations, such as in urban contexts (Solecki et al., 2017).

The following paragraphs discuss the key conceptual contributions in terms of the usefulness of the conceptual framework proposed to assess social contracts for adaptation (see 2.4.2 and 2.4.3).

First, the conceptual framework in combination with the empirical findings on actors' desired adaptation objectives and target actors helped to advance the current conceptual literature on social contracts for adaptation in two ways: Firstly, adopting a critical realist lens, the different taxonomical levels of objectives observed suggest the need for future research to sharpen the distinction between specific objectives attached to adaptation measures, underlying objectives and overarching goals and visions. While this analysis focuses on the empirically observed specific objectives, the underlying objectives and overarching goals and visions were harder to capture comprehensively across the data. Second, in contrast to much of the current conceptual literature on social contracts for adaptation that focuses on the negotiation of roles and responsibilities towards forming a coherent social contract, the empirical analysis suggests the crucial role of clarifying and aligning adaptation objectives first to turn the discussion from "who does/should do what" to "how do we get there". Given the role of actors' desired adaptation objectives in shaping their perceived roles and responsibilities, the framework allows to examine this link that could contribute to overcoming gaps in both respects – between the different realms of social contracts (imagined, practiced and legal) as well as in moving towards a Type 1 and ideally Type 2 social contract (Figure 13).

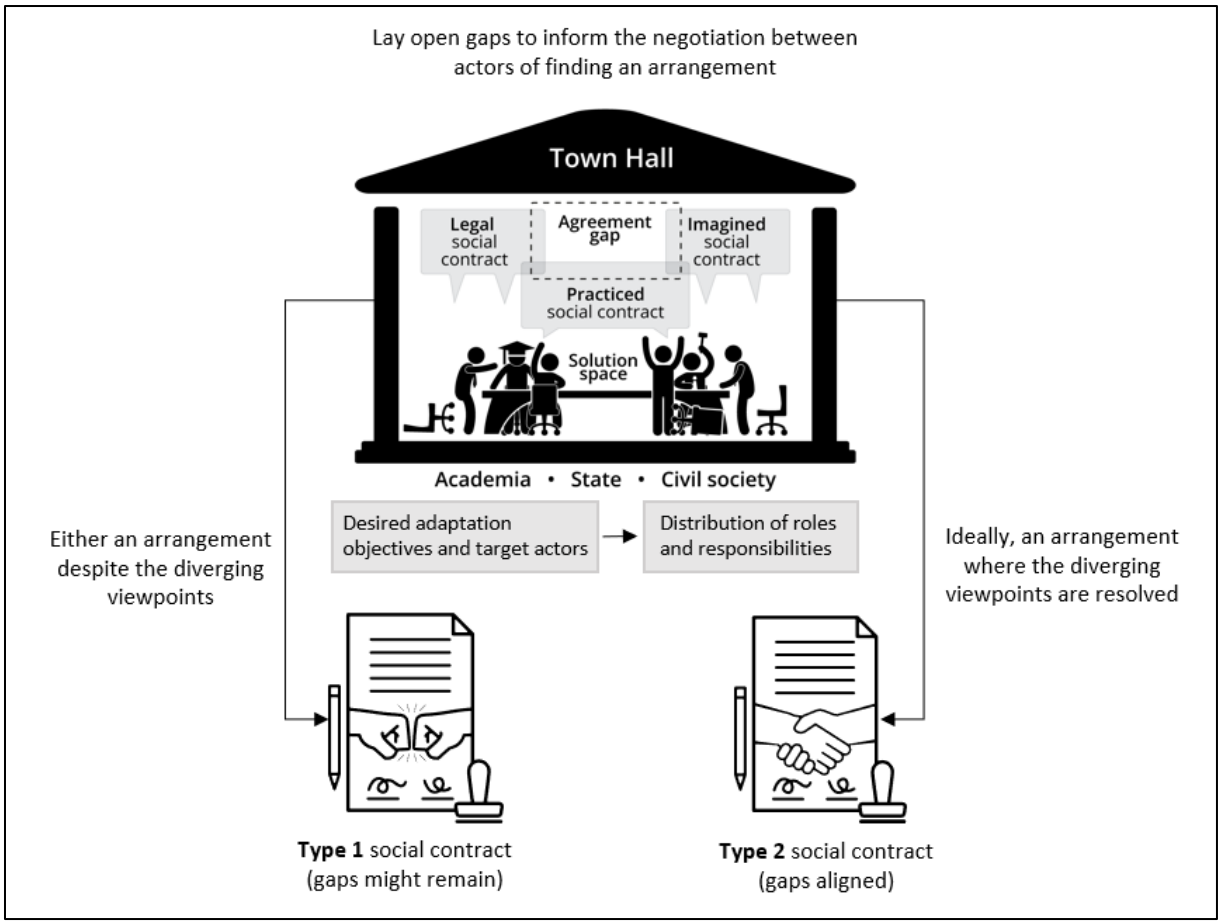

Figure 13: Shaping coherent social contracts for adaptation, source: own draft, building in part on (Garschagen et al., forthcoming) (with graphical support from Andrés Alegria)

Second, the distinction between the two types of social contracts on the basis of the level of agreement (or disagreement) into a Type 1 social contract (where actors' visions and perceptions on mutual distributions of roles and responsibilities do not align but seek to mediate differences) and a Type 2 social contract (where actors' visions and perceptions on mutual distributions of roles and responsibilities align and they seek a contract to explicate them) proved to be very useful. This distinction particularly helped to respond to the critique raised in the adaptation literature on the notion of consent put forward by classical theorists. The need for a collective societal agreement is challenged, considering that adaptation takes place in a socially contested space and the formation of a Type 1 is going to be more likely than a Type 2 (ideal) social contract. In particular, in multi-actor constellations where different actors have diverging perceptions on what kind of adaptation should be pursued, for whom, and by whom, such as in Mumbai and many other societies that are confronted with heavy pressure to adapt, the need for a Type 1 social contract is important. In other words, even if actors' viewpoints clash, which in reality is most often the case, especially in cities, a Type 1 social contract could help to mediate these clashes and gaps between different viewpoints. Hence, clashes do not have to be reconcilable in order to have viable social contracts, but a social contract is still needed to deal with the clashes for actors to be able to move forward. In contrast to previous literature, where a social contract is often understood to represent consent and agreement

on the goals and visions as well as the distribution of roles and responsibilities (Type 2), the study thereby makes a significant contribution by distinguishing the two types.

Third, the three-fold conceptual distinction proposed by Blackburn & Pelling (2018) into imagined, practiced, and legal-institutional realms provided valuable insights into the gaps and mismatches between the different realms, as shown in the empirical findings from Mumbai. This conceptualization helped to lay open gaps between actors' adaptation objectives (see 6.2) and distributions of roles and responsibilities (see 6.3) that they imagined or expected, perceived as formally codified or practiced. The actor-specific lens adopted in this study enabled the focus on the 'imagined' and therefore, the perceived gaps between the realms. In other words, the study could analyze how different actor groups perceived the gaps between the realms of social contracts. The relationship between the three forms might be valuable to answer questions such as, to what extent adaptation policy and governance arrangements reflect (whose) visions and expectations on roles and responsibilities, who is formally ascribed to play a certain role and to what extent does this reflect in reality or whose adaptation visions and goals are translated in practice.

The central focus of this study was to understand 'imagined' social contracts and their relations to the practiced and legal realms. Their importance is underscored by the fact that not only are they shaped by the practiced and legal realms, but also influence them. This makes it urgent and important to better understand the different ways in which actors imagine and expect adaptation visions and the distribution of roles and responsibilities to achieve them. The empirical findings affirm the need for improving our hitherto very patchy theoretical and empirical understanding of imagined social contracts, as well as the need to develop methods to capture and assess them. While such an analysis might be particularly easier to conduct in a democracy due to a stronger expression of expectations, such as in the context of India, it might be even more important in the context of other forms of government where an expression of the different envisioned viewpoints is even harder to capture. Social listening, including an explicit qualitative sentiment analysis proved to be particularly innovative and useful in identifying and assessing the gaps – especially between the different imagined and other realms of social contracts.

Fourth, despite the conceptual distinction between roles and responsibilities, the empirical findings revealed the challenges in comprehensively capturing actors' perceived roles as opposed to responsibilities, which were often found to be easier to articulate by actors in relation to specific adaptation measures. What the empirical evidence also suggests is the need to understand actors' rationales for why they ascribe certain responsibilities to different actors – which could potentially help to shed more light on actors' expectations on adaptation roles. While the qualitative sentiment analysis could provide some indication (such as feelings of frustration, apathy, disappointment), future research can develop this approach further. Much of the current adaptation literature uses roles and responsibilities synonymously, confirming the fuzziness of the concepts (see 2.1.5).

The above paragraphs discussed the key contributions of the study to the current conceptual literature on understanding and assessing social contracts for adaptation – in particular on laying open and making explicit the gaps between diverging viewpoints (Figure 13). The findings from this step (and study) aim to inform the next two steps toward shaping coherent social contracts for adaptation – to assess if and how actors negotiate these diverging viewpoints and finally, examine whether and how they settle at an arrangement which helps to moderate unresolvable gaps in

expectations (Type 1 social contract) and ideally arrive at a shared vision and how roles and responsibilities for adaptation should be distributed (Type 2). In this regard, the study could surpass the initially posed research question (RQ 1) and provide a concrete entry point for negotiating gaps and shaping coherent social contracts for adaptation – aligning actors' desired adaptation objectives and target actors.

The empirical findings suggest that aligning actors' desired adaptation objectives and target actors (who the adaptation measure is intended to benefit) is an important first step on the way to negotiating gaps in social contracts – before negotiating the distribution of roles and responsibilities. The study shows how actors' adaptation objectives and target actors shape their perceptions on the distribution of roles and responsibilities (cf. 5.3) and thereby highlight the importance of better understanding the link between actors' desired adaptation objectives and responsibilities, which has been rarely examined, at least explicitly, in the literature on social contracts for adaptation (cf. 2.2.2). While actors could be empirically observed to negotiate specific adaptation options on the table and potentially the specific responsibilities attached to them, they are guided by a deeper level of motivations – their underlying objectives that shape their desired adaptation objectives and target actors. The theory of principled negotiation offers some support for this conceptual premise, arguing that negotiations should focus on understanding underlying interests instead of stated positions (Fisher and Ury 1981). Transferring this step to the negotiation of social contracts for adaptation would imply a deeper understanding of actors' underlying objectives to align the gap between actors' desired adaptation objectives and target actors as an entry point.

6.6 Transferability

6.6.1 Empirical transferability

While this research was conducted using the case study of Mumbai, a city that is at the frontlines of climate change being at high risk to flooding, both currently and in the future, the findings may have broader implications beyond this specific case to other cities and urban areas that face similar challenges. These could include cities that share similar risk profiles, e.g. in terms of high physical and socio-economic exposure to natural hazards and vulnerability, but also for instance those that are characterized by very heterogenous groups in society with potentially diverse and diverging goals and viewpoints. It might be particularly relevant and useful to transfer and test these findings in heterogeneous societies where diverse actor groups need to come together to find an agreeable pathway to adaptation, under high pressure and very uncertain trajectories of future exposure and vulnerability trends. Cross-learning from different case studies and cities would also help to contribute to the IPCC's upcoming Special Report on Cities and Climate Change.

The findings from Mumbai on the perceived evaluation of adaptation options could be of high relevance and transferred for empirical testing to megacities such as Jakarta, Manila, Bangkok and Ho Chi Minh City in South-East Asia that display similar risk profiles and fragmentations in societies along different lines of division. A limitation in empirical transferability might be in the case of small and mid-sized cities, which might be confronted with different and possibly more challenging constraints in terms of human and economic capital, labor, political attention, etc. In contrast to Mumbai, where political debates take place rather explicitly and openly, in line with the country being the world's largest democracy and having a long history of freedom of speech[6], it could be

[6] Freedom of expression on online platforms is currently being revised in the framework of a new "Digital India" act.(The Economist, 2024b)

particularly useful (yet potentially more challenging) to transfer and empirically test the findings in other high-risk cities in countries where freedom of expression, freedom of the press and open participation in public debates is more limited.

Although the specific characteristics of the context of Mumbai may limit the generalizability of the findings, the underlying principles might be of high relevance to test and assess in other contexts. For example, while sentiments of frustration, anger, and disappointment helped to identify gaps in social contracts in Mumbai, there could be other sentiments or tools that help to understand such gaps in different empirical settings. Given that this PhD is embedded within the TRANSCEND project, which is designed as a comparative case study approach using the cities of Mumbai and Jakarta, it provides a concrete next step of this research, i.e. to transfer and test the empirical findings from Mumbai by application of the approach to Jakarta. While it was initially planned to transfer the approach to both cities from the beginning of the PhD in the project, it was not possible to implement due to the Covid pandemic-related travel restrictions.

6.6.2 Methodological transferability

The biggest potential for transferability of this study lies in the transfer of social listening as a methodological approach for assessing social contracts for adaptation in urban areas and beyond. Certain inherent characteristics of several social media platforms, such as their extensive reach beyond geographical boundaries and advantages in terms of data collection at different scales, speeds, and costs, make the methodological transfer highly feasible. Moreover, with developments in AI-assisted machine learning technologies, the use of crowd-sourced social media data, in combination with satellite data among other sources, holds much potential for further development of mixed-methods studies using social listening and combining qualitative as well as quantitative approaches.

Empirically, India provides a very relevant case with a rapidly growing 'digital population' but also due to social media's increasing popularity as a platform for expressing diverging viewpoints, for example, marginalized voices of women from different castes (Arya, 2024; The Economist, 2024b). However, with almost two-thirds of the global population on the internet and 95% of the digital population on social media, there is a large scope for expanding the use of social listening to other countries (Statista, 2024a). Moreover, in terms of time spent on social media, emerging countries in Asia and Africa, broadly top the list, e.g. Nigeria, Philippines and India (World Economic Forum, 2022).

The advantage of social listening in capturing tacit and implicit expectations and viewpoints of different actors allows for the approach to be valuable for understanding debates on several issues in the negotiation of social contracts for climate change adaptation debates in cities and other societal contexts. In view of finding social listening as personally the most interesting, relevant, and exciting avenue for future research in social contracts for climate change adaptation, further potential is presented below in section 6.7. Beyond social contracts debates, the findings also revealed that almost one-third of the Tweets mainly included weather and waterlogging updates which provide relevant insights for flood hotspots mapping, early warning and emergency preparedness. For example, a recent initiative on mapping flood hotspots in Mumbai used crowdsourced Twitter data by asking citizens to share local waterlogging updates in an effort to improve real-time flood warnings (Tripathy et al., 2024).

At the same time, the transferability of social listening is not without challenges. Changing data protection and privacy laws are shifting the nature of certain online spaces (e.g. Facebook) from a public town square to an algorithmically generated privately perceived town square of individuals (The Economist, 2024a). Among the plethora of social media platforms, each having a different function, popularity between different social, economic, and demographic groups, who has access, and how the platforms influence how different actors communicate, requires careful consideration in the research design on which social media platform is most appropriate for the specific case study or issue. Further, the issue of a social desirability bias in interactions on social media also need to be acknowledged when transferring the approach to other platforms and contexts. In this study, while social desirability bias could have played a role in influencing actors' viewpoints and is acknowledged, the advantage of the approach in limiting the researcher's own influence and ability to collect unsolicited viewpoints provided novel empirical insights.

6.6.3 Conceptual transferability

The conceptual framework guiding the analysis of social contracts for adaptation is aimed to be widely applicable – both, as a whole as well as in its individual elements or characteristics. In the case of the latter, for example, the framework can be used to analyze the gaps and relations between the practiced and legal realms of social contracts by triangulating empirical findings with a formal and informal plan/policy analysis. Similarly, the conceptual focus on actors' desired adaptation objectives and target actors could further be transferred to conceptual debates on adaptation effectiveness and adaptation goals.

Although the conceptual framework here is illustrated with its application in a large coastal megacity in the context of flood risk, the social contracts lens is aimed to be more widely applicable to other human-environmental interactions in other societal and cultural settings as well as other hazard contexts globally. While the elements of the framework are transferable to other societal contexts, the results of its empirical application are only transferable to a limited extent due to the highly context-specific nature of adaptation. Hence, empirical testing and validation by applying the framework to other societal contexts is necessary to improve the robustness and explanatory power of the conceptual framework. In view of the context-specific nature of adaptation, the deductive application of dimensions, adaptation objectives, and roles and responsibilities would need to be flexible enough to accommodate inductive insights. For example, actors might suggest different roles and responsibilities, ascribe different actor groups, have varying desired objectives, and target actors. Empirical applications would further enrich the framework, and the framework is seen here to provide a skeleton to guide empirical analysis of social contracts.

6.7 Future research recommendations

First, while the study could identify and make explicit gaps in many respects and provide some reasons for why they might exist, in order to understand if and how actors navigate these gaps, a deeper analysis of the nature of these gaps is required. The findings suggest that some non-state actors perceived gaps in adaptation goals and visions to persist, implying that laying open the gaps are not going to automatically translate into efforts to close them. For example, interview data confirmed previous literature where they emphasized the continued success of physical infrastructure-based projects at high environmental and social costs, despite protests by civil society and its impacts on past flood events. Potential reasons suggested through the data and

confirmed by previous literature include the engineering training of officials in the municipal authorities that tend to focus on 'taming' approaches, related profit motives for real estate, and hard-to-change 'locked-in' development projects (Mehta et al., 2021). This contribution highlights the need for future research to therefore go beyond identifying the implicit and difficult-to-capture gaps and also delve deeper into understanding why these gaps exist in the first place. The findings from Mumbai raise a very pertinent question for understanding transitions of cities across different risk management regimes – what explains the observed inertia in the city's flood risk management approach that actors perceive as a reinforcement of the status quo? The question invites a critical reflection on whether and how these gaps might be (re)produced and likely prevent a transition to more sustainable adaptation pathways for certain sectors and populations of the city. While the findings provide some strong hypotheses to explore around aspects of institutional inertia triggered by path dependencies and asymmetric power relations, further empirical testing through more fieldwork is required in future research. Hence, the study acknowledges that laying open gaps – which is already very challenging – is a first and important but not sufficient step toward negotiating coherent social contracts for adaptation.

Second, resulting from the most innovative contribution of this study, i.e. in method development by exploring social listening to assess social contracts for adaptation, a major avenue for future research lies in understanding the role and effects of social media spaces (also beyond Twitter such as TikTok, Facebook, Whatsapp etc.) using social listening in catalyzing climate change adaptation debates. The role of social media is developing in diverse and diverging ways. The enormous growth and influence of social media platforms over the last decades have been confirmed by several statistics that show the number of hours spent on social media per day, number of followers of influencers who can be seen as opinion leaders in this sphere, number of likes, re-tweets, comments, and shares that reveal the level of engagement by different users (Jo Dixon, 2024a, 2024b; The Economist, 2024c). This tremendous reach and popularity of social media has changed the way people communicate, express, and inform themselves and brings many opportunities. For example, they have the potential to trigger and popularize social movements (e.g. #MeToo, #FridaysForFuture), act as catalysts of change through viral videos that can transcend geographical, political, social, economic, cultural, and linguistic divides, and provide platforms to people for voicing concerns they would potentially not have in real-world settings. However, social media spaces also bring risks, e.g., using AI to generate fake reels, spread hate speech, and create echo chambers (Cinelli et al. 2021). Beyond users of social media, both public and private sectors have an important role to play in shaping the digital space through regulations, accessibility, and costs. An exciting question for future research, therefore, becomes, if social listening can expose fault lines in societal viewpoints, is it driving further fragmentation, or is it a frontier of catalyzing change?

Third, in addition to social listening, given the implicit and tacit nature of actors' perceived expectations and visions on the distribution of roles and responsibilities for adaptation, further methodological advancement is needed to capture the 'imagined' dimensions of social contracts from diverse actor perspectives. Methods such as world cafés or serious games such as role-play simulations could be explored for capturing different actor groups' interactions and negotiations of their different priorities, roles and responsibilities (Rumore et al. 2016).

Fourth, a future step of this research is to triangulate the findings of this study with the household survey data collected in Mumbai to include the 'direct' perspectives of the vulnerable, affected

households. Furthermore, another identified gap in the literature has been on the role of the private sector in adaptation. Future studies on social contracts for adaptation to climate change could explicitly include or focus on the private sector. In the case of Mumbai, as the empirical findings have shown, the indirect yet powerful role of the private sector in influencing land-use planning would make it a worthwhile actor group to include in future assessments.

Fifth, in the multi-dimensional evaluation of adaptation solution spaces, the findings invite future assessments to explore other criteria or factors that might be important to actors' decision-making and evaluation, which are not reflected in the six dimensions put forward in the current literature, for example, mental wellbeing or political risk of failure. Methods to capture synergies and trade-offs between options, portfolios, and dimensions, as well as dynamics over space and time, present an important research need, especially in the face of cascading events and as many options start to hit limits and shrink the potential solution space.

Lastly, in view of the large lacking empirical evidence on the negotiation of social contracts for adaptation, there is a critical need for future research in adaptation to focus on making explicit adaptation goals, intended beneficiaries, and distribution of roles and responsibilities. As a start, future studies could explicitly assess these questions in case studies. Going beyond scientific literature, a potential research agenda in this regard might be a suggestion as part of a Global Adaptation Mapping Initiative 2.0 that assesses grey literature (missing from the current GAMI initiative) and collects evidence on adaptation goals and visions as well as roles and responsibilities defined in for example, projects funded by the Adaptation Fund, Green Climate Fund, planning documents such as the National Adaptation Plans or policy documents such as the Adaptation Communications submitted by countries to the UNFCCC. A potential first scoping database could be the Climate Policy Radar (Climate Policy Radar, n.d.).

6.8 Relevance and contributions at the science-policy interface

The above recommendations and research needs are further underscored by their timeliness and relevance to global debates and processes at the science-policy interface, especially given the seventh assessment cycle of the IPCC kickstarted this year, which places a significant emphasis on adaptation. This priority reflects the need of governments for "policy-relevant, timely and actionable scientific information" for the second Global Stocktake under the Paris Climate Agreement in 2028. The social contracts lens and findings from this study aim to contribute to the negotiations and political debates that will take place at varying scales ranging from the local (e.g. city networks) to the global (e.g. UNFCCC COP), as different actors need to work together in delivering on the goals and commitments set in their Nationally Determined Contributions (NDCs), National Adaptation Plans (NAPs), and goals and targets under the Agenda 2030 for sustainable development (SDGs). The conceptual findings from this study aim to provide an organizing structure for the burgeoning research required and upcoming in this field, especially in laying open gaps, mismatches, and tensions between different actor groups and realms of social contracts. In other words, the questions raised by focusing on imagined social contracts i.e. 'what kind of adaptation do we want' and 'how do we want to get there' are of high relevance to guiding climate policy negotiations.

The heuristic assessment frameworks for evaluating the perceived adaptation solution spaces for desirability and feasibility, adaptation objectives and roles and responsibilities, and adaptation

progress could be useful for informing the debates and technical dialogues that will start in 2026 for the Global Stocktake, especially in the components addressing adaptation progress. Findings from such assessments could also be synthesized and of relevance to the UNEP's annual flagship Adaptation Gap report.

In particular, the findings could contribute to the Global Goal on Adaptation, especially in the design of a Monitoring, Evaluation and Learning (MEL) system that aims to assess collective progress on adaptation (UNFCCC, 2015). Against the background of these major scientific and policy processes, the negotiations of adaptation goals and visions as well as the distribution of roles and responsibilities for adaptation to climate change will be (and are already) front and centre of many debates, least of all for allocation of adaptation finance to the most vulnerable. Which adaptation goals and visions are pursued, for whose benefit and how the roles and responsibilities are distributed will have important implications on the allocation and distribution of adaptation finance. The urgency of this question is underscored by the growing adaptation finance gap (United Nations Environment Programme, 2023) and a critical concern at the upcoming COP 29 in Azerbaijan this year where important decisions on climate finance will need to be taken, such as the revision of the USD 100 billion goal (Alayza, 2023). A social contracts lens could offer an important analytical lens for assessing the distribution of adaptation finance.

The methodological contributions hope to inform and stimulate method development for capturing knowledge gaps in adaptation priorities, needs, capacities, and expected allocations of roles and responsibilities that could support decision-making, planning, and implementation. With the rapid expansion of social media, the expected increase in the 'digital' population, and the increasing role of social network platforms, social listening demonstrates the potential to be scaled up and applied at a global scale for a range of policy-relevant topics. Big data, including social media data, in combination with the rapid development of AI-based technologies and methods, hold unprecedented potential for gathering and assessing evidence so urgently needed for tracking adaptation progress.

The empirical findings from Mumbai provide useful insights from a highly relevant case study, especially for the Special Report on Climate Change and Cities commissioned under the IPCC's seventh assessment cycle. Given the importance of social contracts for adaptation in cities and urban areas in particular, the empirical findings and illustration of the framework from flood risk management in Mumbai could be of relevance to this report, specifically to knowledge gaps on governance and institutions. The research priorities for this report have identified the need for inclusive governance models and knowledge on multi-level governance arrangements between state as well as non-state actors that allow to reconcile conflicts and manage trade-offs in an effort to drive joint adaptation forward.

Hence, the findings of this study are considered to be also of relevance to major policy processes and debates, reports, and initiatives at the science-policy interface.

7. CONCLUSION

This study has been developed to contribute to the understanding and assessment of coherent social contracts for fostering societal adaptation efforts by addressing the identified research gaps. Societies across the globe are confronted with heavy pressures to adapt to the increasing impacts of climate change, often in a socially contested space given that they are characterized by multi-actor constellations with potentially diverging viewpoints on important questions such as what adaptation goals and visions are envisioned, whose interests are they designed to serve and how the roles and responsibilities for achieving these goals are to be distributed between different actors. These questions served as an entry point for undertaking the study presented here. Despite the notion of 'social contracts' having been argued in the previous literature for its usefulness, it has remained little conceptualized in the context of adaptation and largely lacks empirical understanding in this regard to date (cf. 2.2), partly stemming from methodological challenges in capturing the often implicit and tacit expectations that actors have on the above questions.

Against the background of this overarching aim of the study to understand and assess social contracts for adaptation, important gaps could be observed in the current scholarship that the study aimed to address. First, despite the established importance of coherent social contracts for adaptation, detailed conceptual and theoretical applications and frameworks, especially for guiding empirical analyses to the adaptation context, have been largely lacking until now. Second, a growing research and policy need and related gap pertain to an understanding of actor-specific adaptation objectives and target actors, given the highly context-specific and contested nature of adaptation. Third, although previous studies have highlighted the importance of a clear distribution of roles and responsibilities for adaptation, limited scientific attention has been paid to understanding actors' expectations on the distribution of roles and responsibilities for adaptation. Fourth, closely related to the previous gaps is the methodological challenge in assessing social contracts, especially with regard to actors' desired adaptation objectives and expectations on the distribution of roles and responsibilities, which are often tacit and implicit in nature, making them rather difficult to capture. Finally, a major step on the way to achieving coherent social contracts for adaptation requires an understanding of how different actors perceive and evaluate their adaptation solution spaces in terms of their feasibility and desirability in a real-world setting, which has been mostly lacking in the current adaptation literature. In addressing the above-identified gaps, the study argued for the relevance of social contracts for urban adaptation (cf. 2.3). The importance of coherent social contracts for adaptation is most starkly illustrated in cities, especially in dynamically urbanizing and growing economies such as India, as it is here that one can find the confluence of high risk, severe adaptation challenges, and heterogeneous societal groups with different levels of exposure and vulnerability, and potentially diverging viewpoints on adaptation.

The study was designed to address the above-identified research gaps and adopted a three-fold objective. Firstly, it aimed to advance the current conceptual understanding of social contracts for adaptation, especially by defining and providing a framework for guiding empirical assessment. The second aim of this study was to operationalize the framework and empirically assess actors' adaptation objectives and perceived distributions of roles and responsibilities for adaptation, by drawing on the case study of flood risk management in Mumbai. In doing so, it aimed to understand how actors perceive and evaluate their adaptation solution spaces for adaptation in terms of their feasibility and desirability. Finally, the study set out to explore and develop the novel approach of

social listening on Twitter to assess social contracts for adaptation, next to more conventional methods of expert interviews and participant observation.

The study presented here could contribute to the current scientific knowledge on adaptation across conceptual, empirical, and methodological realms and address the observed research gaps in five key respects. Resulting from the discussion of the main findings and contributions of the study (6.1 – 6.5), the study can draw the following conclusions:

First, the actor lens in the multi-dimensional evaluation of adaptation solution spaces helped to capture the stark gaps and mismatches between state and non-state actors. This approach enabled to distinguish the assessments of desirability from feasibility in actors' evaluations of different adaptation options. In combination with the empirical analysis, the actor-specific approach thus allowed to advance current multi-dimensional evaluations of adaptation solution spaces that largely draw on literature and integrate the notion of desirability into feasibility. Further, applying the heuristic framework to the empirical context of Mumbai details the different perspectives between state, civil society and academia on the current and envisioned adaptation solution space. The starkly contrasting views, for example, on the dominant physical infrastructure-led approach to flood risk management in Mumbai reveal the wide gaps that actors (will need to) negotiate. These findings are regarded as important because on the way toward achieving coherent social contracts for adaptation, it is crucial to understand actors' perceived solution spaces in terms of not only which adaptation options they emphasize but also how they evaluate them. Forming coherent social contracts for adaptation will require actors to negotiate their diverging viewpoints, and in that respect laying open the ruptures in actors' perceived solution spaces reveals the mismatches and gaps that actors will need to deal with and ideally reconcile. In other words, these findings matter because they reveal conflicting viewpoints on the evaluations of the options themselves that are/might be on 'the negotiating table'.

Second, the study contributes to the current conceptual and empirical literature on social contracts for adaptation by providing an explicit focus on actors' desired adaptation objectives and target actors, so far only implicitly considered. While the study could lay open the contestations between state and non-state actors, the social contracts lens further allowed the identification of the gaps between adaptation objectives at the imagined, practiced, and legal-institutional realms. The findings suggest a link between actors' adaptation objectives and perceived roles and responsibilities – which has rarely been examined in the literature. The significance of this contribution to the debate on social contracts for adaptation is that the findings suggest that it is of high importance to first align actors' objectives and target actors, before negotiating roles and responsibilities. Yet, it is acknowledged that this is difficult to capture and lay open, given the often implicit and tacit nature of actors' desired adaptation objectives, which for example, might also be hidden due to their politically sensitive nature. In this way, the research provides an entry point for the negotiation towards shaping coherent social contracts for adaptation. The context-specificity and contested nature of such objectives show that assessing the effectiveness of adaptation and defining 'successful' adaptation is not without challenges. At the same time, the empirical contributions further expose the challenges for science and policy in defining and operationalizing a global level goal for adaptation to measure and track adaptation progress.

Third, the study contributes to the empirical evidence on social contracts for adaptation by assessing actors' perspectives on the distribution of roles and responsibilities for adaptation. While the analysis strengthens the calls in the current literature for clear roles and responsibilities, the detailed empirical insights lay open the challenge of how to resolve conflicting and ambiguous viewpoints between actors as well as between the imagined, practiced, and legal realms of the distribution of roles and responsibilities for adaptation. The rifts revealed in these two respects, especially in relation to the starkly opposite views on the protection of vulnerable populations through social listening on Twitter, highlight the importance of laying open the gaps in actors' expectations on the distribution of roles and responsibilities for adaptation. The findings on both, actors' desired adaptation objectives and perceived roles and responsibilities further underline the need for a better understanding – conceptually and empirically – of imagined social contracts for adaptation (and its relations to practiced and legal realms), so far largely lacking in the current literature.

Fourth, the innovative approach using social listening on Twitter allowed for capturing unsolicited, therefore open viewpoints of different actors, in a large N sample and almost in real-time. The researcher's positionality could be limited to a large extent in the generation of the dataset and thereby proved to be useful in capturing actors' implicit and tacit expectations and contributing to a novel method for assessing imagined social contracts. The burgeoning role and importance of social media platforms such as Twitter in the exchange and negotiation of diverging views, often compared to a 'digital marketplace', render it an important and growing database for developing social listening approaches to assess social contracts for climate change adaptation. The qualitative analysis of sentiments proved to be a useful tool in identifying and understanding the reasons for actors' expressions of disagreement on the distribution of roles and responsibilities for adaptation. In contrast to the quantitative approaches, the qualitative manual coding helped to grasp nuanced sentiments such as frustration and sarcasm, thereby going beyond the positive, negative, or neutral classification derived through machine learning approaches based on algorithms. Sentiments could, therefore, provide a useful entry point in understanding actors' tacit expectations, especially when they are ambiguous or unable to articulate them clearly. This could be applied to other platforms, for example, through an assessment of emoticon reactions, to other contexts and countries, and serve as a helpful entry point in identifying gaps in social contracts.

Finally, the study has contributed to advancing the conceptual understanding of social contracts for adaptation. Based on the empirical analysis, which revealed astonishingly wide gaps and stark disparities between actors' desired adaptation objectives and expectations of roles and responsibilities they ascribed to different actors, the study shows how important it is to lay open and understand the gaps and disagreements to inform the negotiation of coherent social contracts for adaptation. This could be an arrangement wherein actors negotiate social contracts despite their differences in viewpoints (Type 1). Ideally, though, the findings aim to inform a Type 2 social contract wherein actors have resolved their differences and seek a contract to explicate their agreement. The study has revealed the importance of understanding actors' underlying objectives and rationales for ascribing responsibilities in this regard. Finally, this research suggests that aligning actors' desired adaptation objectives provides a helpful entry point in the discussion to form coherent social contracts for adaptation.

Despite the significant contributions of this study, certain limitations need to be acknowledged. The overarching motivation of this study was to understand and assess social contracts for adaptation by

drawing on empirical insights from Mumbai. The mixed methods approach adopted in this study, including social listening on Twitter, semi-structured expert interviews, and participant observation, allowed to capture important segments of the social contracts debate in Mumbai, yet it does not claim to provide a complete assessment and understanding of social contracts debate in Mumbai. While social listening captures an important segment of the debate taking place in the increasingly popular virtual space of social media platforms such as Twitter, a major challenge associated with it is the representativity of populations. This is linked to the "digital divide" - according to which participation often traces the contours of digital literacy, affordability, and accessibility to the internet. In the Mumbai context, while the Twitter debate allowed to capture the empirically often lesser-studied perspectives of the middle classes and elite, these groups are likely overrepresented in comparison to the most vulnerable populations. Nevertheless, the views of the vulnerable are still represented to some extent by civil society organizations, individuals, and academia in Twitter debates and through triangulation with interviews and participant observation. However, it is important to bear in mind that they might have their own biases and political agendas, which are difficult to identify. Hence, their views cannot be read as representative of the directly affected vulnerable populations. For this, triangulation with household survey data that captures the 'direct' perspectives of vulnerable populations is an important step for future research – which was initially planned but could not be undertaken due to pandemic-related travel restrictions.

Further, viewpoints may be affected by a social desirability bias and suggest a gap between online and offline perspectives. On the one hand, this can be argued as problematic because it does not reflect the 'real' views of the actors. On the other hand, precisely because of the unsolicited nature of data collection, the views could be more reflective of the real-world setting and be 'open' in comparison to views that could be captured in an "artificial context", e.g. of a household survey or expert interview (Andreotta et al., 2019). A recent example from India supports the latter, wherein social media platforms are providing an emerging space for voices that are otherwise marginalized in the 'real world' (Arya, 2024).

Given that the study primarily aimed to understand differences between actor groups – such as state, civil society, and academia, in their perspectives on the adaptation objectives and distribution of roles and responsibilities, the research acknowledges that it could not yet comprehensively capture differences within actor groups. While the study could identify and highlight the conflicting views within certain actor groups, for example, between different individuals in the Twitter debate, triangulation with other methods, such as focus groups, could allow for a more fine-grained perspective on intra-actor conflicts.

Finally, the main contribution of the study has been in capturing diverging viewpoints between actors and realms of social contracts (imagined, practiced, and legal-institutional) in the evaluation of perceived solution spaces, which is an important, yet the first step toward informing the discussion for actors to form coherent social contracts for adaptation. While the study has made important contributions to the scientific literature on social contracts for adaptation, the boundaries of its contributions and potential for transferability are acknowledged (6.6). Hence, the study has raised several open and relevant questions for future research under three overarching steps – laying open, making explicit and understanding the often tacit and implicit gaps (and why they exist) in social contracts, assessing if and how actors negotiate diverging viewpoints, and finally, examining whether and how they arrive at an arrangement to reconcile these diverging perspectives.

Based on these conclusions, this study calls for future research to devote increased efforts to understanding and informing the process of shaping coherent social contracts for adaptation, which is most urgently needed in societal contexts that are at the nexus of high adaptation pressure and diverging, conflicting or potentially competing perspectives, yet lack a clear, mutually agreed upon vision and strategy to drive adaptation forward (cf. 6.7). Cities and urban areas, especially in rapidly growing economies, present a highly relevant and important empirical setting for such analyses. In doing so, the study suggests that an important step in this direction would be through further empirical work in understanding the multi-dimensional evaluation of perceived solution spaces for adaptation to develop a more robust framework. Further, transferring and investigating diverse empirical settings, especially where capturing these implicit and tacit viewpoints might be more difficult but making it all the more important to make them explicit. The emphasis on the 'imagined' realm of social contracts presents a frontier for future research – exploring novel methodological approaches to capture the envisioned goals and expectations of actors for adaptation. The study calls for enriching conceptual and theoretical understanding of this realm, which is not only shaped by but also influences the de facto and de jure realms of social contracts. Laying open the gaps between the imagined and its relation to legal and practiced realms has the potential to not only reveal gaps due to historical reasons or in the status quo, but also provide an entry point for understanding future visions, aspirations, and expectations for adaptation. In this regard, the novel methodological approach of this study in developing social listening on Twitter suggests that exploring the social media space and other digital platforms of exchange can be of great relevance to capture diverse perspectives and contribute towards laying open contestations in adaptation debates. Hence, the study puts forward several questions for future adaptation research to shape coherent social contracts for adaptation, which are urgently needed to advance adaptation efforts across the globe.

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Appendix

A1. Qualitative codebook

Axial code	Primary code	Description	Example
Religion		This code applies to Tweets which invoke spiritual or religious intervention, offer prayers in support of individuals affected by floods or address a God in relation to monsoon.	A tribute to the monsoon woes of #Hindmata waterlogging at Parel. Franklin Paul & friends recreated Hindmata area in the Ganpati Decoration. Pic courtesy Ratik Chorge @HTMumbai #MumbaiWeather https://t.co/ASDw4Q37OJ
Stock markets		Tweets which link trends in the stock market to monsoon and flooding. Mumbai houses the headquarters of the National Stock Exchange of India.	Mera desh badal Raha hai Aagey bad Raha hai. #MumbaiRains #StockMarket #nifty #sensex #traderslife #nseindia https://t.co/56V7fVM9f3
Climate change		Tweets which allude to the impacts of climate change on Mumbai	#Mumbai municipal commissioner Iqbal Singh Chahal says by 2050, a major portion of south Mumbai, including the business district of Nariman Point and state secretariat Mantralaya, will go underwater due to #RisingSeaLevels ↴ https://t.co/FeV6QzYjRp
Food		Tweets which refer to food that is especially related to monsoons and rains in Mumbai.	Thing's that can't be separated in Monsoon! #MumbaiRains Bhajiya & Chai BMC & Open Manhole https://t.co/LduYkKtXTe
Weather updates	Cyclones	Tweets that provide updates related to cyclones which may have an impact on Mumbai. (This dataset excludes the Tweets related to cyclone Tauktae which struck Mumbai in mid-May 2021, since Tweets were collected corresponding to the official monsoon period in Mumbai between June-September)	#CycloneGulab will make start making landfall by 8pm over #tekkali in Srikakulam district, AP. It will turn into a deep depression later. #mumbairains to increase from Mon 11 pm. If it will be mod to heavy OR heavy to very heavy will depend on how close it passes from #Mumbai https://t.co/1LoCLkLK1t
	Weather updates		
	Waterlogging updates		
	Warnings		
Romanticizing rain		This code is applied to Tweets in which actors romanticize the rain and monsoon in	Overcast but Beautiful . .

		Mumbai. This code is often in relation to expressing the natural beauty of the rain, links to Bollywood, enjoying certain food items in the monsoon rain etc.	My Beautiful city with dark grey monsoon clouds in the background . The Bay , Mumbai . #mumbai #mumbairains #artdeco #sea #view #sky #monsoon #weekend #weather #nft #NFTartist https://t.co/aUwGj5dbUA
Environmental conservation		Tweets which call for protection of biodiversity and ecosystems and impact of environmental destruction on flooding.	This is exactly what happens when we chop down trees, concretize every nook and corner.....& then paint trees & grass on a wall with a message.....'Plant Trees and Save Trees'. #Mumbai will keep flooding #ClimateCrisis #ClimateAction Pic @diptivsingh https://t.co/5yWfRnoYCG
Social contract	Social contract	This code applies to Tweets which directly raise concerns or questions in relation to roles and responsibilities for flood risk management.	Tragic to hear of so many rain related deaths in Mumbai. Happens every year, deaths are reduced to a statistic. It seems max city is less prepared to face upto the brunt of the rain waters.. houses on hillocks live on edge year after year with no solution in sight. Prayers!🙏
	Accountability	This sub-code applies to Tweets which raise questions of accountability for the perceived roles and responsibilities by actors.	Whole Mumbai is flooded with rains & incompetence corrupt BMC management instead of visiting war room & taking charge CM @OfficeofUT along with Rashmi Thackeray is enjoying long drive to Pandharpur. Govinda Govinda!!
Middle class		This code refers to Tweets which describe the view of the middle classes in Mumbai.	Mumbai's middle class summed up: "As long as there are no potholes, no water and electricity cuts, Ola, Uber and Swiggys, and the trains run on time, why should we middle class people get involved in politics? Just work for some years and try and get US, UK or Aussie Citizenship"
Bollywood		This code applies to Tweets that make references to Bollywood actors or the industry in its role towards flooding, share pictures of Bollywood actors in relation to monsoon, share film references to the Mumbai monsoon.	How come after such heavy “rain drops” not a single celeb posting or tweeting abt the situation in mumbai? Or all those post r script written just like their dialogues n all done only for money! Where is the love for amchi mumbai?
Praise	Citizens	This sub- code refers to Tweets which praise civil society for their efforts towards dealing with the impacts of flooding.	Nothing can stopped us Team #SharingandCaring #fooddistribution #miraroad #mirabhayandar thank you all for your constant support 🙏 #MumbaiRains #mumbairain #Mumbai #covidhelp https://t.co/35L3XU6vqk
	State	This sub-code refers to Tweets which praise state actors for their support and response in dealing	Taking a moment to thank @MumbaiPolice for their relentless work especially during #Mumbai rains ☔ Year after year, we see them at traffic lights, drenched, helping citizens, rushing victims to

		with the impacts of flooding.	hospitals. Do you stop to even smile at them? #India IN https://t.co/oqaIUkUJW9
Risk regime		This code refers to Tweets which express opinions on risk management regimes, transitions or the lack thereof.	For decades, @mybmc has been unable to fix the flooding at King's Circle, Matunga. See the situation today. And we are the richest civic body in the entire country. Vote these haftawallahs out in 2022. #MumbaiRains https://t.co/6SUs8zeIRa
Sarcasm/ Humour		This code is applied to Tweets that particularly express the sentiment of using sarcasm and/or humour in stating their view on flood risk management.	Delhi & Mumbai flooding due to swindling of funds meant for drainage system. Kejriwal & Thakre are trying to give a look of Venice to Delhi & Bombay 😎🏝
Excluded	Not relevant	This code refers to Tweets which may have made it into the dataset because of the keyword and/or hashtag filter but are not relevant to the debate on flood risk management in Mumbai	#StopEatingMeat #Bakrid #EidAlAdha #BakriEid #MumbaiRains #HeavyRains #NelsonMandelaDay Hey #PETA (@peta & @PetaIndia), Bakrid is coming. Are you afraid to talk about animal cruelty on Muslim festivals ? #BakraLivesMatter https://t.co/cEkTHjj5hi
	Unclear	This sub-code refers to Tweets which may have made it into the dataset because of the keyword and/or hashtag filter but their exact relation to the debate on flood risk management in Mumbai is unclear to the authors.	जो मुँह तक उड़ रही थी, अब लिपटी है पाँव से, बारिश क्या हुई मिट्टी की फ़ितरत बदल गई .... #MumbaiRains #Monsoon2021 Translated by Google: The one who was flying till the face, is now wrapped around the feet, It rained, the condition of the soil changed.
Mumbai spirit			17 people died today in Chembur…rainy season has just started..people are crying their houses are filled with dirty water..cars are floating…mumbai is flooding… Mumbai is running only on Mumbaikars spirit!!
Event		This code refers to Tweets that provided an informational update about an event that will take place/took place.	Panel Discussion on Chitale Fact Finding Report 2006 on Mumbai Rivers and Infrastructure The event is remembering the catastrophic incident of the July 26, 2005 Mumbai floods When: Sat, July 31 2021 at 4:30PM Facebook Live- https://t.co/kjLkBZmdvp #river #infrastructure #26July https://t.co/Mi5leQaXI7
Call to action	Request support	This sub-code is assigned to Tweets that express a request for support in view of the impacts of flooding.	On July 16, 2020, i was near the building after collapsed due to heavy rain and also the building was in detoriated condition that led to this tragedy of 20+ dead. Now the rainy season is due in July requesting @mybmc, @mayor_mumbai to please take care of detoriarating buildings. https://t.co/EwXpU9lCwj
	Call to action	This sub-code refers to Tweets which	Maharashtra floods: Mumbai has some of richest people in world, they should help, says Sanjay Raut |

		express a call for action on flood risk management (including preparedness and relief)	Mumbai News - Times of India https://t.co/R8kMjbc0GE
Covid		This code is assigned to Tweets that refer to management and/or impact of the ongoing Covid pandemic on flood risk preparedness and management.	CM Uddhav Balasaheb Thackeray has directed the state administration to be alert as a 4-day heavy rainfall prediction has been issued for Mumbai & Konkan. The treatment of patients must not be affected &, if needed, shift citizens from vulnerable establishments to safer places.
Complaints	Radar	This sub-code refers to Tweets while complain about the functioning and use of the Doppler radars in monsoon weather predictions.	Mumbai is vulnerable to extreme rain events during monsoon so for that purpose local Doppler radar is very important to warn people. It's been over 3 weeks IMD Mumbai Radar not working. Local media needs to cover this story. This has happened way too many times last few years.
	Ecosystems	This sub-code refers to Tweets which express complaints about the condition of ecosystem protection.	16 years on, Brimstowad drainage system still unfinished. Wetlands of Mumbai are concretized, mangroves are being uprooted. Walls are built in our rivers and natural nullahs. Coastal road is just one of the reasons. The more reclamation, more water will keep clogging Mumbai. https://t.co/5acyKJ32XN
	Potholes	This sub-code refers to Tweets which complain about potholes on roads.	Hard to believe but true. ₹48 crore spent on filling 33,000 potholes this monsoon in Mumbai. ₹14,000 spent on fixing each pothole. But roads full of potholes even now. https://t.co/BmhQLOmxEd @VinodMishra4U @mihirkotecha @rais_shk @AmeetSatam @ShelarAshish
	Electricity shortage	This sub-code refers to Tweets which complain about electricity shortage as an impact heavy rainfall.	In last 2.5hrs it has rained 127mm between 9.30pm to 12am. All from b2b #Thunderstorm formation ⛈️ No #electricity in #Badlapur #west from 11pm.. #Winds gust also touched 68km/hr.
	Building collapse	This sub-code refers to Tweets which complain about the conditions of buildings leading to building collapses during heavy rainfall in the monsoon.	On July 16, 2020, i was near the building after collapsed due to heavy rain and also the building was in detoriated condition that led to this tragedy of 20+ dead. Now the rainy season is due in July requesting @mybmc, @mayor_mumbai to please take care of detoriarating buildings. https://t.co/EwXpU9lC
	Drainage	This sub-code refers to Tweets which complain about the condition and cleaning of the drainage system before the monsoon.	Tax payers money down the drain? In 10 years, BMC spent Rs 7000 crore on desilting, Storm Water Drain works reveals RTI filed by BJP MLA AmeetSatam. ₹1000 crore spent on nullahsafai alone but Mumbai still floods @AUThackeray @mihirkotecha https://t.co/MR26fYbxYo @chaitanya_pm

	Waterlogging	This sub-code refers to Tweets which complain about the impacts of waterlogging as a result of flooding.	Vasai: 70-year-old man sits in flooded water to protest against waterlogging in his ground-floor flat https://t.co/NJ4GI5PNgx
	Exams	This sub-code refers to Tweets that complain about the conditions for being allowed to write important exams in the event of heavy rainfall and flooding. In some Tweets, actors describe impacts of flooding and related difficulties which pose challenges for students to prepare and appear for exams.	They reached 20 min late , due to heavy rainfall. Exam was scheduled at 10 AM. @CMOMaharashtra @PawarSpeaks @AjitPawarSpeaks Please allow them to appear in the ESE exam. Their life and 2 years preparation is on stack... Maharshi Dayanand College Parel Mumbai. #ESE2021 https://t.co/cLWIdaS3eD
	General preparedness	This sub-code refers to Tweets which complain about the overall state of preparedness towards the annual monsoons and heavy rain-related impacts including flooding.	First spell of #mumbairain's and see the preparedness of @mybmc Visuals of Dadar . https://t.co/IhIM0viuIQ
	Manholes	This sub-code refers to Tweets which complain about the open manholes that pose severe threats during floods.	Two women walking along a flooded footpath in #Mumbai fell into an open manhole evoking outrage from city residents. https://t.co/96E97gGu3J
	Media	This sub-code refers to Tweets which complain about the role of media and coverage of flooding related issues.	I strongly believe that natural disasters which happen (vastly more frequently) in places that aren't the US and Europe should receive equal coverage The question is why so many people in the US and Europe don't care about the rest of the world https://t.co/lsZhEVGhmp
	Reclamation	This sub-code refers to Tweets which complain about the impacts of reclamation on flood risk.	Mumbai flooded? Mithi overflowing? If we tinker with floodplains what else can we expect? This is Aarey Metro Depot plot where natural floodplain was filled up A plot that was lower in level than Mithi river (zoom in) The result of filing up floodplains is for all to see today https://t.co/Vr7qjwPyRX
Locations mentioned		In the absence of geo-referenced Tweets, this code was assigned to Tweets	Andheri Subway waterlogged in #Mumbai as rain continues to lash the city. (Video credit: ANI)

		which contain the name of a location.	#MumbaiRains #MaharashtraRains https://t.co/1ANzjsohpN
Transport	Not affected	This sub-code was included in the first round of coding for transport infrastructure that was not affected due to flooding.	
	Boat	This sub-code refers to transport-related Tweets which provide an update on water/boat transport	In a few weeks, Navi Mumbai may just be a #watertaxi ride away from south Mumbai. The Maharashtra Maritime Board (MMB) will be holding a trial run of water taxi service between Belapur in #NaviMumbai & Mumbai in October. @IndianExpress @maha_tourism https://t.co/zBTJSbofw4
	Railways	This sub-code refers to Tweets which share updates, impacts and preparations for the functioning of Mumbai's railway services – the lifeline of the city.	Reviewed monsoon preparedness of Mumbai Suburban for making a roadmap & precautionary plan. Examined current status of vulnerable areas & devised a plan for smooth functioning of trains. We are committed to ensure no inconvenience is caused to Mumbaikars as monsoon begins. https://t.co/TVW53U7noR
	Bus	This sub-code refers to Tweets which provide updates on the impact of flooding on bus travel	Mumbai: Due to heavy rain and waterlogging in low-lying areas, buses have been diverted. https://t.co/If8JMzkRzh
	Solutions	This sub-code refers to Tweets which share transport-related measures in adaptation to flooding	To make the crucial road transport route floodproof, the Maharashtra government plans to ask the National Highway Authority of India to build flyovers on the Mumbai-Bengaluru highway. https://t.co/xtTnOTr1Qd
	Traffic update	This sub-code refers to Tweets which provide traffic-related updates due to the impact of flooding.	#Mumbai Traffic Police says #Andheri Subway will remain closed every day from 10 pm to 6 am (21st June- 30th September), for traffic to avoid any accident or loss of life due to waterlogging #MumbaiRains
	Flights	This sub-code refers to Tweets which provide information on the impact of flooding on flight travel	#6ETravelAdvisory: Due to waterlogging in some parts of #Delhi and #Mumbai, we advise passengers to keep enough travel time in hand while travelling to the airport. To check your flight status please visit https://t.co/TQCzzy2a2s. Stay Safe!
	Access	This sub-code refers to Tweets which show the impact of flooding on access to services dependent on	Gokul largest milk brand will not be able to supply milk to Mumbai on Saturday. Flooding in parts of the state --Kolhapur, Sangli, Konkan & closure of state & N.highways has affected the transportation & Milk collection #MaharashtraRains #MumbaiRains

		transport infrastructure.	@fpjindia
	Roads	This sub-code refers to Tweets which highlight the impact of road infrastructure on flooding as well as the impact of flooding on roads.	Hello Coastal road fans. This is the situation in Mumbai with just few hours of rainfall today. We wonder what would be the fate of the road so close to sea & that underneath via tunnels. Will it be viable for cars or boats/ submarines🤔 #SaveOurCoast #CoastalRoad #MumbaiRains https://t.co/cXnQ4BBfkp
Response		This code refers to Tweets which describe a response measure taken or suggested in view of flood risk mitigation.	The pumping station at Mogra nullah, with a capacity of pumping out 42,000 litre water per second, is all set to be made, and the pumping station at Mahul nullah is awaiting few clearances from GoI https://t.co/pe17wcOGAp via @IndianExpress
Preparedness		This code refers to Tweets which describe a response measure taken or suggested in view of flood risk preparedness.	Considering IMD's heavy rainfall forecast for the next 4-5 days in Mumbai, CM Uddhav Balasaheb Thackeray has directed @mybmc & all agencies to be prepared for any eventualities, work around the clock in close co-ordination to tackle them. All rescue teams must be on stand-by.
Luxury problem		This code is assigned to Tweets which describe luxury problems related to impact of flooding.	Daughter - if it was offline school would have surely got a holiday today. Hope atleast some teachers face network issues to compensate for the lost holiday. 😂😂😂 #mumbairain
Impact		This code refers to Tweets which describe impacts of flooding, mostly in terms of deaths.	"More than 30 people have died in the Indian city of Mumbai after an intense burst of rainfall caused a landslide and wall collapse, as changing monsoon patterns due to climate change lead to more extreme rains across India." https://t.co/ekyVzwV0pc
Sympathy		This code refers to Tweets expressing sentiments of sympathy towards impacts of floods on humans and animals.	Pained to know about house & wall collapse incidents in #Chembur , Vikhroli & Bhandup in Mumbai. Heartfelt condolences to families who lost their loved ones. Praying for the speedy recovery of the injured. #MumbaiRains
Water supply		This code refers to Tweets which state the impact of flooding and heavy rainfall on water supply in the city.	Due to the inundation of rain water in the Bhandup Water Purification Complex, the Filtration and Pumping plants at the complex had to be shut down as a precautionary measure. Due to this, water supply in most of the parts of Mumbai has been disrupted today (July 18, 2021)
Corruption		This code refers to Tweets which suggest the corruption involved in measures related to flood risk management	Rain, rain, go away... Global Tenders are on the way... Come again another day... Meanwhile PR is on the sway !!! #MumbaiRains #Corrupt_Mcgm https://t.co/MJJsCF5rbl

Philanthropic action		This code refers to Tweets which describe philanthropic measures taken towards individuals affected by floods.	Bengali news paper article - 70 new houses by Salman Khan for flood affected victims in #Mumbai Man with golden heart @BeingSalmanKhan https://t.co/jdo1K8vPAy

A2. Guiding questions for the semi-structured interview:

1. What is your opinion on the current state of adaptation to flood risk in Mumbai?
2. In your expert opinion what needs to be changed most urgently in flood risk management in Mumbai and why?
3. What would be your vision for Mumbai in terms of successful flood risk management?
4. What is preventing Mumbai from transitioning into that vision?
5. What are ways to overcome these challenges?

**Please note that questions were kept broad to allow for follow-up questions and the interviewee to bring up topics which were relevant in their opinion.*

A3. Guiding questions for the "heuristic mapping of actor-oriented multi-dimensional evaluation of adaptation options based on interviews"

Steps	**Explanation**	**Guiding questions**	**Assessment**	**Corresponding code**
Identification and categorization of adaptation options	The first step involved identifying adaptation options that the experts talked about and categorized them into the following types (based on IPCC AR6 Chapter 6): 1. Social infrastructure, 2. Nature-based solutions, 3. Grey/Physical infrastructure. We added a fourth category, developed bottom-up from the data – 4. Hybrid options (which combined one or more of categories 1-3).	Which adaptation options are identified? Which category does the identified adaptation option fall into?	1. Institutional changes 2. Nature-based solutions, 3.Grey/Physical infrastructure 4. Hybrid options	Type
Actor-based identification of adaptation options	In a next step, the actor who identified the respective adaptation option is categorized.	Which actor identified which adaptation options?	State Civil society Academia	Actor
Overall desirability of the adaptation options	We aim to capture the overall role in which the actors emphasize or discuss the identified options, i.e. positively, negatively or mixed. In other	How does the actor emphasize the overall role (desirability) of this option? 1. Does the actor	1. Positive 2. Negative 3. Mixed	Desirability

	words, we split the notions of desirability and feasibility of the identified options – in contrast to Singh et al. who combine both under "feasibility". They capture desirability to some extent under the social dimension of socio-cultural acceptability. Furthermore, they justify it on the grounds of not being able to capture desirability of an option based on a global assessment of adaptation options, given the actor/context based nature of desirability. However, in this case, we see merit in disaggregating the characteristics of desirability and feasibility because an actor may perceive an adaptation option as highly desirable (and hence categorized in the analysis as overall positive), although it may not be seen as highly feasible. The reverse could also be true where actors may perceive an option as not desirable (and hence it would be categorized as negative), despite being highly feasible for eg. in terms of economic resources and technical know-how available. Hence, while desirability captures the preference of an option by an actor, feasibility is seen to indicate the possibility of implementation of the option.	perceive this option as desirable? 2. Does the actor perceive this option as not desirable? 3. Is the actor having mixed opinions about the option?		
Feasibility of dimensions which were identified	We mapped the feasibility of the dimensions that were emphasized by the actors. Actors did not emphasize all dimensions for each option. For eg. in the case of some options only two or three out of the six dimensions	Which of the six dimensions did the actor emphasize in discussing the identified option? Within the identified dimensions, did the actor emphasize the dimension to:	1. Positive 2. Negative	Feasibility

	were mentioned. In contrast to Singh et al., we do not only look for if a dimension was perceived as a barrier but also if the dimension was viewed as an enabler. From the identified dimensions by the actors, it was further classified into positive or negative roles.	1. act as a driver and play a more enabling role? Or 2. rather as a barrier and play a more constraining role in discussing the identified option?		

A4. Description of codes

Codes	**Description**
Adaptation option	Refers to the adaptation measure or action identified by the actor.
Category Sub-codes: - Grey/Physical infrastructure - Green/Natural infrastructure - Institutional changes - Hybrid	Type of adaptation option
Overall desirability (positive/negative)	Indicates if the actor expresses desirability for an adaptation measure (positive) or is not in favour of it (negative)
Feasibility dimensions Sub-codes: - Environmental - Economic - Technological - Institutional - Social - Geophysical	Environmental dimension describes the impact of environmental factors in positively enabling or negatively constraining the identified adaptation option. For eg. the adverse impact of salt water on mangroves would be categorized as a constraining environmental dimension. Economic dimension refers to the role of financial resources, costs, economic vulnerability, economic interests and factors relating to economic development on the adaptation measure. Technological dimension describes the role of technical aspects such as technological knowledge, capacity, infrastructure etc. on the adaptation option. Institutional dimension describes the role of institutional change, governance reforms, measures relating to awareness, capacity building, policy changes etc. in the feasibility of adaptation measures. Social dimension refers to the role of aspects such as social vulnerability, cohesion, cultural and behavioural characteristics, beliefs, values etc. in influencing the feasibility of the adaptation option. Geophysical dimensions refer to the physical, hazard related aspects in defining the potential of the adaptation option.
Role of dimension Sub-codes: - Enabling/positive - Constraining/negative	Each identified dimension was further coded to show if the actor perceives the role of the dimension as an enabling/positive factor or rather as a constraining/negative factor in the feasibility of the identified adaptation option.

A5. Overview of semi-structured expert interviews

Interviewee code	Actor group	Role/position	Date of interview	Duration	Place
R1	Civil society	Vice-president	25.10.2021	1h8m	In-person
R2	Academia	Researcher	03.10.2021	1h1m	Virtual
R3	Civil society	Communication strategist/ex-journalist	30.09.2021	57m	In-person
R4	Civil society	Founder/Activist	21.06.2021	1h10m	Virtual
R5	Civil society	Executive Trustee	29.09.2021	25m	In-person
R6	Civil society	Trustee	21.04.2022	1h10m	In-person
R7	State	Deputy Municipal Commissioner	14.10.2021	45m	In-person
R8	State	Deputy Chief Engineer	14.10.2021	35m	In-person
R9	Civil society	Founder	27.04.2022	1h24m	In-person
R10	Academia	Assistant Professor	27.09.2021	50m	In-person
R11	Academia	Professor	02.05.2021	1h14min	Virtual
R12	Academia	Assistant Professor	17.09.2021	35m	Virtual
R13	Academia	Assistant Professor	20.04.2022	1h12m	In-person
R14	Academia	Associate Professor	25.10.2021	1h6m	Virtual
R15	Academia	Associate Director	30.07.2021	41m	Virtual
R16	Academia	Adjunct Associate Professor	22.04.2022	1h05m	In-person
R17	State	Deputy Municipal Commissioner	20.10.2021	45m	In-person
R18	State	Additional Municipal Commissioner	20.10.2021	35m	In-person
R19	State	Joint Director	06.10.2021	1h20m	In-person
R20	Academia	Associate Professor	10.08.2021	26m	Virtual
R21	Academia	Consultant	19.10.2021	1h11m	In-person
R22	Academia	Executive Director	28.09.2021	1h30m	In-person
R23	Civil society	Journalist	25.09.2021	1h13m	Virtual
R24	State	Officer on Special Duty	20.10.2021	45m	In-person
R25	Civil society	Founder	30.10.2021	1h15m	Virtual
R26	State	Project Officer	29.10.2021	1h45m	In-person
R27	Civil society	Journalist	07.10.2021	1h	In-person
R28	State	Manager	01.10.2021	21m	In-person
R29	Academia	Associate Professor	27.09.2021	1h13m	In-person
R30	Civil society	Founder	23.05.2022	1h3m	In-person
R31	Civil society	Director	23.09.2021	1h17m	In-person
R32	Civil society	Founder	22.07.2021	50m	Virtual
R33	Academia	Chair Professor	05.08.2021	32m	Virtual
R34	State	Ex-Chief Planner	23.10.2021	2h	In-person
R35	State	Additional Municipal Commissioner	18.10.2021	1h45m	In-person
R36	Academia	Professor	12.05.2022	1h22m	Virtual
R37	State	Additional Principal Chief	07.10.2021	1h15m	In-person