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Social, Ecological, and Technological Strategies for Climate Adaptation

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Chapter 3
Social, Ecological, and Technological Strategies for Climate Adaptation

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Abstract Resilient cities are able to persist, grow, and even transform while keeping their essential identities in the face of external forces like climate change, which threatens lives, livelihoods, and the structures and processes of the urban environment (United Nations Office for Disaster Risk Reduction, How to make cities more resilient: a handbook for local government leaders. Switzerland, Geneva, 2017). Scenario development is a novel approach to visioning resilient futures for cities. As an instrument for synthesizing data and envisioning urban futures, scenarios combine diverse datasets such as biophysical models, stakeholder perspectives, and demographic information (Carpenter et al. Ecol Soc 20:10, 2015). As a tool to envision alternative futures, participatory scenario development explores, identifies, and evaluates potential outcomes and tradeoffs associated with the management of social–ecological change, incorporating multiple stakeholder's collaborative subjectivity (Galafassi et al. Ecol Soc 22:2, 2017). Understanding the current landscape of city planning and governance approaches is important in developing city-specific scenarios. In particular, assessing municipal planning strategies through the lens of interactive social–ecological–technological systems (SETS) provides useful insight into the dynamics and interrelationships of these coupled systems (da Silva et al. Sustain Dev 4(2):125–145, 2012). An assessment of existing municipal strategies can also be used to inform future adaptation scenarios and strategic plans addressing extreme weather events. With the scenario development process guiding stakeholders in generating goals and visions through participatory workshops, the content analysis

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of governance planning documents from the SETS perspective provides key insight on specific strategies that have been considered (or overlooked) in cities. In this chapter, we (a) demonstrate an approach to examine how cities define and prioritize climate adaptation strategies in their governance planning documents, (b) examine how governance strategies address current and future climate vulnerabilities as exemplified by nine cities in North and Latin America where we conducted a content analysis of municipal planning documents, and (c) suggest a codebook to explore the diverse SETS strategies proposed to address climate challenges—specifically related to extreme weather events such as heat, drought, and flooding.

Keywords Climate adaptation strategies · Governance · Resilience planning · Social-ecological-technological system (SETS)

3.1 Social–Ecological–Technological Systems (SETS) Framework

Envisioning how we transform our cities into places and communities that are resilient is an emerging urban challenge that requires an approach integrating diverse knowledge, experience, and perspectives (Muñoz-Erickson et al. 2017). Cities are SETS, and so are parts of cities like neighborhoods, parks, and various types of infrastructure. The SETS perspective is an important aspect of envisioning urban futures because cities are considered as systems, meaning we cannot consider parts of cities—institutions, ecosystems, built environment, and communities—in isolation since they interact to form the whole.

In SETS, social dimensions include social–political–cultural–economic dynamics of a city, including both the decision-making actors and their actions. Ecological dimensions include the biophysical elements of non-human nature, with their associated processes, that are part of the fabric of cities—for example, tree growth or soil formation. Technological dimensions include the built components and associated processes of urban systems, for example, roads or public transportation networks, buildings, and the knowledge embodied in technologies (Markolf et al. 2018). Envisioning cities from a SETS perspective raises valuable governance questions, such as the type of institutions and knowledge needed, as well as which people are affected by infrastructure changes (Kim et al. 2019). How can services provided by natural ecosystems be integrated into the built environment? How can technological advances be used to impart flexibility or redundancy to infrastructure? The SETS approach demands that such questions—reflecting the three SETS dimensions—be answered to build resilience and support sustainable pathways.

The SETS framework for climate adaptation is a pragmatic approach that reflects an increasing recognition of the role that built and technological infrastructure play in mediating the relationships among human activities and ecosystem processes (Grimm et al. 2015; McPhearson et al. 2016). The SETS framework is fundamental to climate adaptation plans because it helps to clarify how interactions among the social–political–cultural–economic (S) and the biophysical (E) domains are mediated through

infrastructure (T). Key SETS components to consider encompass diverse social, ecological, and technological features, as well as where these intersect, since these three dimensions interact with each other in supporting urban pathways to resilient futures. Examples include social–ecological considerations in land use changes, ecological effects of biophilia, or the need for more green spaces on society, and technological–social innovation for mobility or communication (Table 3.1).

3.2 Content Analysis of Municipal Planning Documents and Governance Strategies in SETS

In the face of the growing occurrence of weather extremes, climate adaptation plans are essential governance tools at regional, city, and local levels. Though such plans have been extensively developed at national and international levels, local governments have a vital role in implementing municipal-level climate adaptation strategies that are retrofit to various governance scales, regional climatic characteristics, and urban SETS. In the last two decades, city governments have been developing planning documents such as comprehensive municipal plans, disaster preparedness plans, climate action plans, and sustainability plans meant to advance urban resilience by implementing climate adaptation strategies at local levels (Reckien et al. 2018). City plans and city planning processes embody the goals and actions that cities seek to advance for urban resilience (Bulkeley 2010). Municipal governance is often shaped by various forms of interacting institutions, including governing agencies, policies, formal and informal codes, local knowledge systems, practitioners, public officials, and communities (Folke et al. 2005; Araos et al. 2016; Feagan et al. 2019). City plans express goals that are shaped by the various institutions, as well as guide interactions among institutions to achieve goals, demonstrate suitable governance strategies, and envision achievable expectations and outcomes of these strategies (Carmin et al. 2012). As cities continue to lead urban resilience planning, we analyze municipal planning documents to examine how urban governance structures (with diverse socio–political–cultural and biophysical contexts) plan for climate change. Analyzing plans help us understand what strategies are effective and practical, and how well adaptation strategies are integrated in local governance. As such, governance planning documents provide insight into how cities are framing urban resilience, yet there are few mechanisms to effectively and efficiently highlight the suite of SETS climate adaptation strategies that cities are considering. In the following sections, we provide four essential steps for analyzing governance strategies from municipal planning documents by using the SETS framework in order to support an effective scenario-development process for visioning resilient urban futures.

Table 3.1 Matrix exemplifying SETS features in cities. Here the social, ecological, and technological (S-E-T) domain characteristics (vertical header column) impact/influence the social, ecological, and technological components (horizontal header row) of a city. For example, the bottom-leftmost box indicates the ways in which technology influences society

SETS Domain	Social component	Ecological component	Technological component
Social (S)	Equity; Funding; Public education/engagement; Policy; Culture; Legislation; Public perception; Motivation	Land use (e.g., developed space vs. green space); Land conservation; Environmental advocacy groups; Community environmental action; Environmental regulations	Design standards/codes/plans; Institutional interactions; Standardization; Investment; Economic/social pressures
Ecological (E)	Biophilia; Public parks and preserves; Ecosystem services (e.g., clean air, clean water, etc.)	Habitat; Ecosystem; Water bodies; River systems; Forests; Natural resources	Environmental facilities; Environmental management technologies (e.g., stormwater and sewer systems); Fuel system inputs
Technological (T)	Mobility; Economic activity/opportunity; Communication; Comfort/protection from climate	Pollution (air, water, soil); Resource consumption; Monitoring of ecosystem health; Restoration of degraded ecosystems	Infrastructure; Maintenance/management/upgrades/replacement; Data availability and quality; Modelling

3.2.1 Selecting Municipal Planning Documents

The first step is to choose appropriate documents for analysis. Since our focus is municipal governance strategies for climate change adaptation, the pool of potential documents for analysis is limited to plans that are drafted and published by the city, local, and regional governments, and by local non-governmental organizations. Once the potential documents are identified in a city, three to five dominant governance documents are selected for analysis based on the following criteria.

- Must be an overarching planning document (e.g., General Plans, Comprehensive Plans, Sustainability/Resilience Plans, Climate Action Plans, Common Plans)
- Must be less than five years old, with exceptions if the total number of available documents for analysis in a city is less than three
- Must be relevant to climate change, flooding/heat/drought adaptation, resilience, or sustainability
- If more than five documents are available that fit the above criteria, only those salient to climate change adaptation, sustainability, or resilience are selected. If the document is titled with climate action, sustainability, or resilience, it may be prioritized, otherwise the relevance may be determined by how comprehensively the document focuses on strategic planning for mitigation of climatic risks or adaptation to environmental changes (e.g., comprehensive municipal plans, hazard mitigation plans, disaster preparedness management plans, stormwater plans)
- Match the plans to the spatial scale under consideration (e.g., neighborhood, city-wide, regional, national).

We recommend consultation and validation with city practitioners regarding the priority and relevance of documents to finalize the selection. Using the above section criteria, 30 planning documents from across the UREx SRN cities were selected for analysis. These include a diversity of document types relevant to climate adaptation, resilience, and sustainability. The selected documents were published between 2010 and 2015 at the municipal, regional, and state levels (Table 3.2).

3.2.2 Extracting Governance Strategies

From the selection of municipal plans in each city, governance strategies are extracted by capturing exact quotes from documents. The extraction should focus primarily on quotes that describe implementation strategies relating to extreme weather events (namely flooding, extreme heat, and drought), actions, or approaches to adapt to climate change or extreme events in general, and governance mechanisms to mitigate, adapt, or respond to events related to climate change. Examples of strategies extracted from across the UREx SRN cities are presented in Table 3.3.

Table 3.2 List of municipal planning documents selected for content analysis of governance strategies among the nine UREx network cities. Each document reflects climate adaptation, sustainability, or resilience

City	Governance level	Date published	Document name
Baltimore	Municipal	2006 (updated 2009)	Comprehensive Municipal Plan
Baltimore	Municipal	2013	Disaster Preparedness and Planning Project
Baltimore	Municipal	2013	Baltimore Climate Action Plan
Baltimore	Municipal	2009	The Baltimore Sustainability Plan
Hermosillo	Municipal	2013–2014	Municipal Development Plan
Hermosillo	Municipal	2015	Plan de Acción Climática Municipal Hermosillo (2015) (PACMUN)/Municipal Climate Action Plan for Hermosillo
Hermosillo	Municipal	2010	Strategic Plan for Storm Sewers
Miami	Municipal	2013	Miami Comprehensive Neighborhood Plan
Miami	Regional	2012	Southeast Florida Regional Climate Action Plan
Miami	Regional	2010	Miami-Dade Green Print: Our Design for a Sustainable Future
New York City	Municipal	2015	One New York: The Plan for a Strong and Just City
New York City	Municipal	2013	PlaNYC: A Stronger, More Resilient New York
New York City	Municipal	2014	New York City Hazard Mitigation Plan
New York City	Municipal	2011 (updated 2014)	PlaNYC: A Greener, Greater New York
Phoenix	Municipal	2015	PlanPHX General Plan
Phoenix	Regional	2015	Multi-Jurisdictional Hazard Mitigation Plan
Phoenix	Municipal	2011	Water Resources Plan
Portland	Municipal	2012	The Portland Plan
Portland	Municipal	2015	Portland's Recommended Comprehensive Plan
Portland	Municipal	2014	Climate Change Preparation Strategy/Risk and Vulnerability Assessment

(continued)

Table 3.2 (continued)

City	Governance level	Date published	Document name
San Juan	Municipal	2003 (updated in 2012)	Territorial Ordinance/Municipal Land Use Plan (I and II)
San Juan	Municipal	2015	Comprehensive Mitigation Plan Update
San Juan	Regional	2015	San Juan Bay Estuary Plan
San Juan	State	2015	Puerto Rico Climate Change Council's Ruta Hacia La Resiliencia
Syracuse	Municipal	2012	City of Syracuse Comprehensive Plan 2040 (including Land Use and Development and Sustainability Chapters)
Syracuse	Regional	2012	Onondaga County Climate Action Plan
Syracuse	Regional	2010	Onondaga County Multi-Jurisdictional Hazard Mitigation Plan
Valdivia	Municipal	2010	Plan Regulador Comunal de Valdivia
Valdivia	Municipal	2015	Sustainable Valdivia: Plan of Action
Valdivia	Municipal	2012	Stormwater Master Plan

3.2.3 Labeling Strategies with Levers and Exogenous Drivers

After strategies are extracted, the individual strategies are first qualitatively coded for the type of climatic drivers being addressed (i.e., exogenous drivers) and the type of policy instruments being implemented (i.e., levers) (Lempert et al. 2003; Wiek and Iwaniec 2014; Iwaniec et al. 2020). In our case, climatic drivers refer to extreme weather events that impact cities, such as floods (urban, coastal, riverine, or non-specific), extreme heat, drought, and non-specific hazards. Policy instruments are governance mechanisms that may be manipulated to mitigate or respond to the impact of these drivers. Examples include research and plan development, intergovernmental coordination, maintenance of built infrastructure, economic incentives, and education and outreach.

Table 3.3 Example of extracted strategies found within the planning documents outlined in Table 3.2, demonstrating how governance strategies differ by document type and by city

City	Document name	Extracted strategy
Baltimore	Comprehensive Master Plan	"Restore and protect at least one mile per year of streams and river basins in floodplains and stream valley" (City of Baltimore 2009, p 139)
Hermosillo	Plan de Acción Climática Municipal Hermosillo 2015 (PACMUN)/Municipal Climate Action Plan for Hermosillo	Encourage planting of trees and expanding local flora (green areas): Implementation of native species when planting new trees and reducing the felling of trees on public roads [Translated from an original quote in Spanish] (p 86)
Miami	Southeast Florida Regional Climate Action Plan	"Review and assess current agricultural best management practices for the state of Florida for its management of projected climate impacts" (Southeast Florida Regional Climate Change Compact 2015, p AG-6)
New York City	One New York: The Plan for a Strong and Just City	"Expand public education efforts so that all New Yorkers know the risks they face during extreme weather events and other disasters" (City of New York 2015, p 225)
Phoenix	Multi-Jurisdictional Hazard Mitigation Plan	"Review existing general plan and zoning ordinance to determine how these documents help limit development in hazard areas" (Maricopa County 2015 p 367)
Portland	Portland's Recommended Comprehensive Plan	"Create a network of distinctive and attractive City Greenways that link centers, parks, schools, rivers, natural areas, and other key community destinations" (City of Portland 2020, p GP3-19)
San Juan	PRCCC's Ruta Hacia La Resiliencia	Develop green infrastructure plans that improve engineered coastal barriers [Translated from an original quote in Spanish, PRCCC 2015 p 79]

(continued)

Table 3.3 (continued)

City	Document name	Extracted strategy
Valdivia	Plan Regulador Comunal de Valdivia	Maintain or increase urban vegetation [Translated from an original quote in Spanish, Valdivia 2010 p 30]

3.2.4 The SETS Codebook

We developed the SETS codebook that helps us identify SETS components of governance strategies based on Denton et al. (2014), Berbés-Blázquez et al. (2017), Burch et al. (2017), and Iwaniec et al. (2020). The SETS codebook (Table 3.4) is developed in an inductive process by encompassing a pool of sample strategies and incorporating previous studies on systems governance analysis. We propose this codebook for analyzing governance strategies to be qualitatively coded by their contents and evaluated by the interaction of social, ecological, and technological domains. As a non-scale, system-level, bridging framework, this coding scheme allows cities and their stakeholders to explore SETS interaction and adaptation strategies associated with them in city to regional-level governance data. In Table 3.5, we include selected examples of governance strategies that are analyzed by the proposed SETS codebook. The outcome of the analysis creates a comprehensive framework to assess climate change adaptation strategies based on their synergies, conflicts, and tradeoffs across SETS domains.

3.3 Conclusion

In this chapter, we present an approach to identify and analyze municipal governance strategies using a SETS framework for urban resilience framework. Assessing governance strategies using a SETS framework is particularly valuable in the scenario-based visioning process. SETS governance strategies help stakeholders understand current dynamics of urban systems and explore adaptation options prioritized at various governance scales, and are thus useful for visioning futures when provided to diverse stakeholders in the process of developing participatory scenarios. Analysis of governance strategies using a SETS framework can explain how cities currently address climate risks and existing system vulnerabilities through governance adaptation mechanisms. We are particularly interested in determining whether planning documents tend to prioritize a particular SETS domain over others (e.g., predominance of technological solutions), and if they adequately consider system relationships. Identifying SETS interactions in proposed and implemented municipal governance plans is an important step in bridging the gap between aspirations and

Table 3.4 The SETS codebook developed to capture SETS components of governance mechanisms in strategies

SETS domain	SETS code	SETS component	Strategies exemplifying component
Social	S1	Social safety nets	Social safety nets and social protection, food banks and distribution of food surplus, municipal services (including water and sanitation), vaccination programs, essential public health services (including reproductive health services), enhanced emergency medical services
	S2	Educational	Awareness raising and integrating into education, gender equity in education, extension services, sharing local and traditional knowledge, integration of local and traditional knowledge into adaptation planning, participatory action research and social learning, community surveys, knowledge-sharing and learning platforms, international conferences and research networks, communication through media, operations training. *S2 includes any type of knowledge transfer to stakeholders delineated within a strategy
	S3	Informational	Hazard and vulnerability mapping, early warning and response systems, systematic monitoring and remote sensing, climate forecast services, downscaling climate scenarios, longitudinal datasets, integrating indigenous climate observations, community-based adaptation plans (including community-driven slum upgrading and participatory scenario development). *S3 involves with data and information development
	S4	Behavioral	Household preparation and evacuation planning, retreat and migration, soil and water conservation, livelihood diversification, changing livestock and aquaculture practices, changing cropping practices, patterns and planting dates, reliance on social networks, grass-root approaches

(continued)

Table 3.4 (continued)

SETS domain	SETS code	SETS component	Strategies exemplifying component
	S5	Economic	Financial incentives (including taxes and subsidies), insurance (including index-based weather insurance schemes), catastrophe bonds, revolving funds, payments for ecosystem services, water tariffs, savings groups, microfinance, disaster contingency funds, cash transfers
	S6	Legal	Land zoning laws, water regulations and agreements, requirements to support disaster risk reduction, laws to encourage insurance purchasing, defining property rights and land tenure security, eminent domain protected areas, marine protected areas, fishing quotas, patent pools and technology transfer
	S7	Institutional	New research, cross-institutional coordination, partnerships, changes in institutional structure. *S7 captures interactions among agencies (including governmental institutions, non-governmental organizations, and public–private partnerships)
Ecological	E1	Ecosystem-based	Ecological restoration, wetland and floodplain conservation and restoration, increasing biological diversity, afforestation and reforestation, conservation and replanting mangrove forest, bushfire reduction and prescribed fire, assisted migration or managed translocation, ecological corridors, ex situ conservation and seed banks, green and open space
	E2	Green infrastructure	Green infrastructure (e.g., shade trees, green roofs), urban gardens, rain gardens, engineered or constructed ecosystem services
	E3	Ecosystem management practices	Community-based natural resource management, adaptive land use management, controlling overfishing, fisheries co-management, ecosystem focused plan, management of natural resources and ecosystem features/services

(continued)

Table 3.4 (continued)

SETS domain	SETS code	SETS component	Strategies exemplifying component
Technological	T1	Built environment planning and design	Urban planning and design, design storm, building codes, standards, engineering, planning and design codes, certification, and specification
	T2	Engineered infrastructure	Seawalls and coastal protection structures, flood levees, sewage works, improved drainage, beach nourishment, pavement, physical buildings, green infrastructure, solar shade, flood and cyclone shelters, elevate buildings, new system construction and existing system modification and improvement
	T3	Infrastructure operation and maintenance	System inspection and monitoring, operator training program, facility and equipment maintenance/repair, drainage cleaning, best management practices (BMPs)
	T4	Technological solution development and improvement	New crop and animal varieties, genetic techniques, traditional technologies, efficient irrigation, water-saving technologies, conservation agriculture, food storage and preservation facilities, hazard mapping and monitoring technology, early warning systems, building insulation, mechanical and passive cooling, renewable energy technologies, second-generation biofuels

viable adaptation actions. Shaping climate adaptation goals and instigating governance strategies by integrating social, ecological, and technological domains in a systems perspective is essential for building urban resilience, and ultimately, for enabling transformation to sustainable pathways toward the resilient future.

Table 3.5 Example of coded strategies using the SETS codebook. To maintain inter-coder reliability, multiple coders analyzed and reviewed each strategy following the suggested codebook in Table 3.4. Before analysis, selected coders were trained according to standardized coding protocol and the codebook to maintain coding coherency across various documents and among coders. SETS codes correspond to SETS components set out in Table 3.4

City	Extracted strategy	Levers	SETS code	Exogenous drivers
Baltimore	"Restore and protect at least one mile per year of streams and river basins in floodplains and stream valleys" (City of Baltimore 2009, p 139)	Flood infrastructure	E1	Flooding Non-specific
New York City	"NYCHA to execute a resiliency program across 33 public housing developments, which will include the elevation and hardening of building systems, flood-proofing, and upgrading infrastructure" (City of New York 2015, p 231)	Research and plan development; Building design; Flood infrastructure	S7; T1; T2	Flooding Urban
Phoenix	"Implement a water harvesting program through the location, design and construction of dual functioning stormwater retention facilities with enhanced recharge elements designed into the basin…as a part of maintaining a Drought Management Plan in conjunction with SRP & APS to lessen the impact of drought" (Maricopa County 2015, p 402)	Stormwater capture; Groundwater recharge; Intergovernmental coordination	S7; E2; T2	Flooding Urban; Drought

(continued)

Table 3.5 (continued)

City	Extracted strategy	Levers	SETS code	Exogenous drivers
San Juan	Review and modify the public transportation routes depending on the effects of sea-level rise, storm surges and floods [Translated from an original quote in Spanish] (PRCCC 2015, p 40)	Transportation infrastructure	S1; T1	Flooding Coastal

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