TeMA

Journal of Land Use, Mobility and Environment

print ISSN 1970-9889 e-ISSN 1970-9870
FedOA press - University of Naples Federico II

NEW CHALLENGES FOR CITIES IN THE TWENTY-FIRST CENTURY

Regenerative Design - Climate Adaptation & Mitigation
Circular Economy - Citizen Agency - Urban Livability

Vol.19 n.1
April 2026

TeMA Journal has the objective of fostering and integrating studies on urban transformation and urban mobility, within a scientific context focused on adapting cities to global warming and oriented towards economic, social and environmental sustainability. The three issues of the 2026 propose articles that deal with the effects of climate change adaptation, reduction of energy consumption, AI-driven solutions to support urban planning, immigration flows, optimisation of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters.

TeMA is the Journal of Land Use, Mobility and Environment and offers papers with a unified approach to planning, mobility and environmental sustainability. With ANVUR resolution of April 2020, TeMA journal and the articles published from 2016 are included in the A category of scientific journals. The articles are included in main scientific database as Scopus (from 2023), Web of Science (from 2015) and the Directory of Open Access Journals (DOAJ). It is included in Sparc Europe Seal of Open Access Journals, and the Directory of Open Access Journals.

TeMA

Journal of
Land Use, Mobility and Environment

NEW CHALLENGES FOR CITIES IN THE TWENTY-FIRST CENTURY:

Regenerative Design - Climate Adaptation & Mitigation - Circular Economy - Citizen Agency - Urban Livability

1 (2026)

Published by
Laboratory of Land Use, Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Italy

TeMA is realized by CAB - Center for Libraries at University of Naples Federico II using Open Journal System

Editor-in-Chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n°6 of 29/01/2008

Editorial correspondence
Laboratory of Land Use, Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples Federico II
Piazzale Tecchio, 80
80125 Naples (Italy)

https://serena.sharepress.it/index.php/tema
e-mail: redazione.tema@unina.it

The cover image was created using an AI tool, taking into account the thematic content of the articles included in this issue.

TeMA - Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.

With ANVUR resolution of April 2020, TeMA Journal and the articles published from 2016 are included in A category of scientific journals. The articles published on TeMA are included in main international scientific database as Scopus (from 2023), Web of Science (from 2015) and the *Directory of Open Access Journals* (DOAJ). TeMA Journal has also received the *Sparc Europe Seal* for Open Access Journals released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe). TeMA is published under a Creative Commons Attribution 4.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

TeMA Journal of
Land Use, Mobility and Environment

NEW CHALLENGES FOR CITIES IN THE TWENTY-FIRST CENTURY:

Regenerative Design - Climate Adaptation & Mitigation - Circular Economy - Citizen Agency - Urban Livability

1 (2026)

Contents

REVIEW NOTES

TeMA
Journal of
Land Use, Mobility and Environment

TeMA 1 (2026) 225-237
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/13361
Received 1st February 2026, Available online 30st April 2026

REVIEW NOTES - Urban practices

Soft adaptation measures for disaster risk reduction and urban resilience. Early warning systems

Stella Pennino

Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: stella.pennino@unina.it
ORCID: https://orcid.org/0009-0008-4439-0078

Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban Practices section aims at presenting recent advancements on relevant topics that underline the challenges that the cities have to face.

This note provides an overview of soft adaptation measures and their role in promoting effective disaster risk reduction and urban resilience. It focuses on Early warning systems (EWS), governance and knowledge-based instruments that enhance anticipatory capacity within urban systems by integrating risk knowledge, hazard monitoring and forecasting, communication and dissemination mechanisms, and response capability. Selected international case examples are discussed, illustrating how cities are operationalizing EWS to address extreme weather events. Finally, the contribution outlines policy implications and research directions, emphasizing the importance of integrating EWS deployment into spatial planning and resilience governance frameworks to strengthen city and community adaptive capacity.

Keywords

Climate change; Soft adaptation measures; Disaster risk reduction; Urban resilience; Early warning systems

How to cite an item in APA format

Pennino, S. (2026). Soft adaptation measures for disaster risk reduction and urban resilience. Early warning systems. *TeMA - Journal of Land Use, Mobility and Environment*, *19* (1), 225-237. http://dx.doi.org/10.6093/1970-9870/13361

1. Introduction: climate change and soft adaptation measures

Global average temperatures continue to rise, with evidence of a growing rate of warming in recent decades (Berkeley Earth, 2026). This accelerating trend is driving an increase in the frequency and severity of extreme weather events and cascading risks (IPCC, 2022). These hazards trigger escalating social, environmental and economic impacts, particularly in urban areas where exposure and vulnerability are concentrated (European Commission, n.d.). This could lead to an increase in both health costs and socio-ecological inequalities that make vulnerable population groups more prone to heat-related impacts (Longato et al., 2025).

In this context of polycrises and deep uncertainty, climate change adaptation and resilience have become strategic priorities to reduce current and future risk and to strengthen institutional, community and infrastructural capacities to cope with disruptive events (UNFCCC, n.d.; UNDRR, 2023). Adaptation options are commonly grouped into broad classes according to the type of intervention they entail (Klein et al., 2014; EEA, 2025). Conventional "grey" measures rely on engineered infrastructure – such as dikes, floodwalls or drainage upgrades – to protect assets from hazards. However, they are capital-intensive, have long lifetimes, and can quickly become inadequate under higher levels of warming or changing risk patterns (Klein et al., 2014; IPCC, 2022). Recognizing the limits of stand-alone grey solutions, "green" measures – such as nature-based solutions, urban forestry and green infrastructure – have emerged as important complementary options that enhance ecosystem services while contributing to risk reduction (EEA, 2025; Anderson et al., 2022). Yet these measures also face constraints, including land availability, context-dependent performance, and the need for continuous maintenance and monitoring to remain effective over time (Anderson et al., 2022; IPCC, 2022).

Building on socio-technical and socio-ecological systems perspectives, recent literature underscores the central role of communities, institutions and practices in shaping risk, while co-producing and operating both grey and green measures (Chappin & Van der Lei, 2014; Hossain et al., 2024). This perspective is particularly relevant for cities, which are increasingly recognized as key arenas of socio-technical change (Pennino, 2025). This has brought renewed attention to so-called "soft" adaptation measures – non-structural or behavioral strategies that manage risk through governance, policy, planning and capacity-building rather than through large-scale physical works (GWP, 2017; Kehler & Birchall, 2023). Many of these measures directly overlay with disaster risk reduction and disaster risk management, for example land-use regulation, early-warning systems, preparedness planning and public awareness initiatives (UNDRR, 2019; 2023).

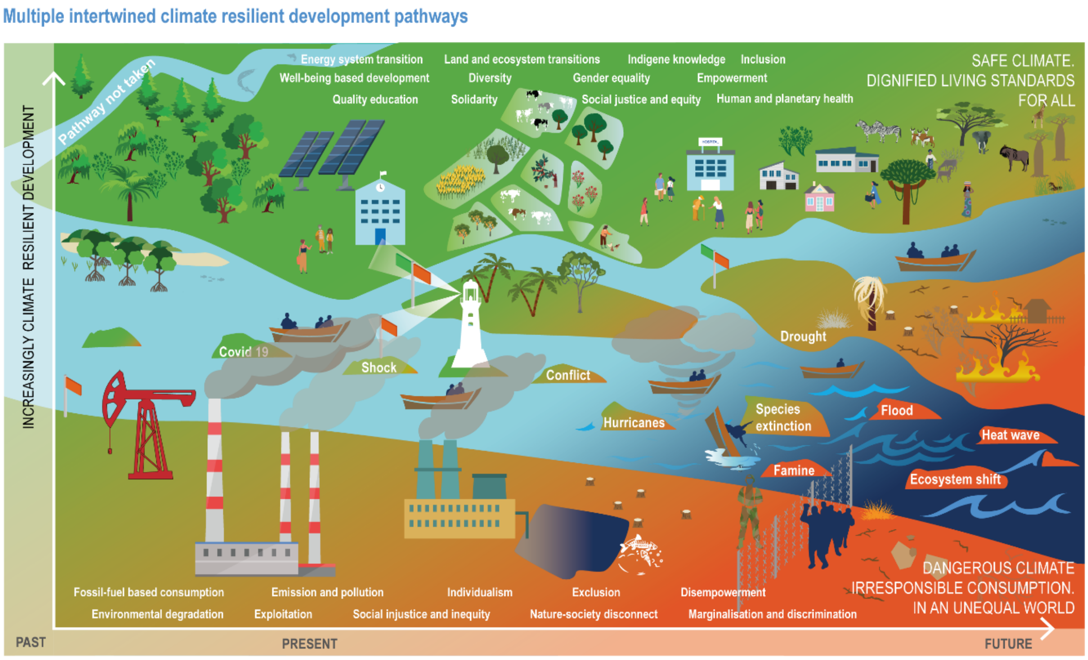

Fig.1 Climate-resilient development pathways

The active interplay between human systems, technology and the environment links climate adaptation to broader sustainable development agendas. Framing adaptation not as an optional add-on but as an integral component of development pathways resonates with the IPCC concept of climate resilient development, which emphasizes the joint pursuit of adaptation, mitigation and sustainable development to reduce climate risk for all (Schipper et al., 2022). This Review Note examines the role of soft adaptation measures for disaster risk reduction and urban resilience, with a specific focus on multi-hazard early warning systems. It also discusses how urban planning can enable or constrain the integrated development of socio-ecological and socio-technical systems that can advance sustainable development while confronting climate change and moving towards more climate-resilient urban futures.

2. Urban resilience and urban planning

Urban planning directly shapes urban resilience by influencing how cities grow, function and are governed. General urban plans and building codes determine the form and performance of the built environment, steering land-development patterns towards more – or less – climate-resilient configurations and mediating the deployment of grey and green adaptation measures (Keith et al., 2023a). They guide land-use allocation, urban design and the integration of greenery, while disaster risk reduction and management plans, hazard mitigation plans and climate action plans articulate policies, governance arrangements and management actions for reliable energy access, public health interventions, emergency management and exposure reduction (Keith et al., 2023b; UNDRR, 2019).

The inherently multidisciplinary nature of urban planning positions it as a key convenor in urban governance and disaster risk management. Strategic and action plans can provide platforms for bringing together the multiple actors involved in disaster risk reduction and management, and for coordinating urban resilience strategies across sectors and scales (UNDRR, 2019; IPCC, 2022). However, fragmented mandates, siloed knowledge and sectoral planning often limit their effectiveness, prompting calls for more integrated approaches that engage stakeholders horizontally – across urban management sectors – and vertically – across local, regional and national levels (Keith et al., 2023a; Oneto & Canepa, 2023). Planners might also lack training in urban climatology or have limited access to usable risk information and tools to translate it into spatially targeted strategies. These challenges underscore the need for closer collaboration with universities, research institutions and other knowledge brokers to embed climate and risk science in planning practice (Keith et al., 2019; IPCC, 2022).

For urban heat, Keith et al. show that resilience requires integrated planning that prioritizes mitigation and management actions for the most vulnerable communities, yet this coordination is often missing in practice (Keith et al., 2023a). Their analysis highlights a lack of clear leadership and coordination in urban heat governance, and identifies a significant opportunity for urban planners to assume a leading role by integrating heat mitigation and management into comprehensive plans, besides hazard mitigation plans and heat action plans (Keith et al., 2023a; 2023b). Concerning urban flooding, the relative ease of spatially visualizing pluvial and fluvial hazards has fostered the development of planning-support tools that operationalize climate risk assessment and monitoring. Truu et al. propose the Extreme Weather Layer (EWL) method, which dynamically links land-development scenarios to the performance of urban drainage systems and other determinants of flood risk, supporting planners in identifying flood-prone areas and testing alternative spatial configurations (Truu et al., 2022). In a complementary review, Oneto and Canepa emphasize the active role of urban planners in flood risk management for climate adaptation, highlighting how their position at the interface between spatial analysis and policy design is crucial for integrating flood resilience into urban development pathways (Oneto & Canepa, 2023). Overall, the role of urban planning in promoting urban resilience is emerging as critical, yet remains only partially realized. Planning can intervene along the full disaster risk management cycle, from risk analysis and assessment to the design of spatial policies, governance arrangements and community engagement processes (UNDRR, 2019; IPCC, 2022). Embedding these functions within integrated and adaptive resilience planning processes can enhance the coherence and effectiveness of both short-term and long-term actions. Within this context, instruments such as climate action plans and heat action plans offer important opportunities to coordinate and mainstream urban resilience strategies across sectors and scales (Keith et al., 2023a, UNDRR, 2019).

3. Early warning systems

With the rapid evolution of information and communication technologies (ICTs), disaster risk reduction (DRR) and disaster risk management (DRM) literature has highlighted a range of innovative strategies to support adaptive urban resilience (UNDRR, 2019; IPCC, 2022). Among these, early warning systems (EWS) stand out as a key soft adaptation measure, leveraging advances in weather and climate observation, forecasting and communication technologies, to protect lives and health in the face of extreme events (UNDRR & CIMA Research Foundation, 2024; UNDRR & WMO, 2025).

EWS can be understood as integrated arrangements of processes, activities and actors that generate and disseminate early warnings – timely and targeted information on imminent or emerging hazards – to enable early action – anticipatory measures by authorities and communities to reduce impacts on people, infrastructure and other assets (UNDRR & CIMA Research Foundation, 2024). Recognizing their central role in DRR, international organizations have strongly promoted their expansion, most notably through the Early Warnings for All (EW4All) initiative. It is organized around four independent pillars: (i) disaster risk knowledge and management; (ii) hazard detection, observation, monitoring, analysis and forecasting; (iii) warning dissemination and communication; and (iv) preparedness and response capabilities (WMO, 2022; UNDRR & CIMA Research Foundation, 2024). EWS can be designed and operated at multiple governance levels – from national meteorological and hydrological services to regional platforms and local, city-scale systems – and differ in how comprehensively they implement and integrate these four pillars (UNDRR & WMO, 2025; UNDRR & CIMA Research Foundation, 2024).

Fig.2 The four pillars of Early Warnings for All

Given the specific exposure and vulnerability of cities to climate-related extreme weather events, Sheehan et al. conducted a global assessment of urban extreme-weather early warning systems in large cities reporting to the CDP Carbon Disclosure Project Cities Adaptation Actions database (Sheehan et al., 2025). They classified city-reported systems against the EW4All pillars and identified substantial gaps in pillars' coverage, geographic uptake, cross-sectoral coordination and public health engagement, particularly in low- and lower-middle-income contexts. While many cities reported health and spatial justice as an objective of their EWS, fewer explicitly assigned roles to health agencies, and few appeared to target the most vulnerable communities, underscoring the need for more comprehensive, multi-sectoral and equity-oriented urban EWS (Sheehan et al., 2025). Their findings provide several critical entry points for DRR and urban resilience from an urban planning perspective.

The first key aspect is the multi-hazard perspective. When viewed spatially, the same urban elements can simultaneously contribute to, and help reduce, different types of risk (IPCC, 2022; WMO, 2025). For example, green spaces can mitigate both heath and pluvial flooding, while dense urban fabrics may provide shading that lowers cooling demand yet also intensify the urban heat island effect and concentrate exposure (Klein et al., 2014; Anderson et al., 2022). Developing multi-hazard EWS therefore demands systemic thinking and planning, encouraging stakeholder engagement and multilevel governance so that trade-offs and co-benefits are understood and managed across hazards and sectors (UNDRR, 2019; UNDRR & WMO, 2025).

Effective EWS also depend on robust spatial risk knowledge, including detailed information on local hazard patterns, exposure and vulnerability (UNDRR & CIMA Research Foundation, 2024). Identifying populations and places at risk, including particularly vulnerable groups, can reveal spatial patterns of inequality and climate injustice that are often embedded in urban development trajectories (Sheehan et al., 2025; IPCC, 2022). This evidence can inform both long-term urban policies – such as zoning, infrastructure investment and housing strategies – and short-term actions, including the targeting of warning messages, the design of communication channels, and the prioritization of field operations by civil protection and emergency services during extreme weather events (UNDRR, 2019; UNDRR & CIMA Research Foundation, 2024).

Finally, the design and operation of EWS require coordinated governance, cross-sectoral cooperation and meaningful community engagement (UNDRR, 2019; WMO, 2022). Establishing networks of relevant city agencies (e.g. planning, health, emergency management, utilities) and co-developing protocols and response plans with local communities are essential conditions for effective local DRR, and at the same time foundational for long-term urban resilience where risk knowledge, preparedness and adaptive learning are embedded in everyday governance (UNDRR, 2019; UNDRR & CIMA Foundation, 2024). To provide empirical insight into how EWS deployment can be integrated within urban planning processes, the following sections present three case studies of urban practices.

Fig.3 Early Warnings for All initiative's logo

1.1 Taipei, Taiwan

Fig.4 Taiwan Weather App

Taipei, Taiwan stands out as one of the most comprehensively documented examples of a fully integrated, multi-hazard urban EWS. The city's system addresses a broad spectrum of hazards – including typhoon-induced flooding, dam failures, windstorms, fires, earthquakes, volcanic activity, explosions and chemical poisoning – reflecting the compounded and cascading risk profile of a dense metropolitan area located in one of the world's most exposed disaster hotspots. Institutionally, the EWS is coordinated across public health, networked infrastructure, social services and city administration, exemplifying the kind of cross-sectoral governance that the EW4All framework identifies as foundational to pillar integration (Sheehan et al., 2025; UNDRR & WMO, 2025). On the technical side, flood control infrastructure leverages an IoT network integrating rainfall and stormwater monitoring with automated pump station operations, and recent advances have incorporated hybrid deep learning models – combining convolutional and back-propagation neural networks – into the real-time urban drainage early warning system, achieving high predictive accuracy for sewer and river water levels at short forecast intervals (Chang et al., 2025). Despite these advances, flood management remains challenging under typhoon-induced extremes, and decades of rapid urbanization in the Tamsui River floodplain have entrenched structural vulnerabilities that no warning system alone can resolve (Su, 2016). Taipei's experience thus underscores a central argument: technically sophisticated EWS, however effective in reducing mortality in the short term, must be coupled with land-use governance and long-term spatial planning reform to address the root drivers of urban exposure.

1.2 Rio de Janeiro, Brazil

Fig.5 Alarm sirens in a favela in Rio de Janeiro

Rio de Janeiro, Brazil offers a paradigmatic case of a city-level EWS that evolved iteratively in response to repeated disasters, gradually expanding from single-hazard monitoring to a horizontally integrated, multi-agency arrangement. The primary hazards addressed are rainfall-induced landslides and flash floods – hazards disproportionately affecting favela communities on steep hillsides and low-lying floodplains, where informal settlement, deforestation and inadequate infrastructure converge to produce high and unequally distributed vulnerability. The system's technical architecture combines a rain gauge network and Doppler radar managed by GeoRio, the municipal geotechnical office, with the community-based alert and alarm system (A2C2), which operates through a two-tier protocol: Civil Defense agents transmit SMS alerts to trained community leaders at the first level, while imminent threats trigger sirens and mandatory evacuation at the second (Ortigao, 2013). Institutionally, the Center of Operations Rio (COR), established in 2010, centralizes data from over thirty agencies and serves as the coordinating body for all warning and response actions (Sandholz et al., 2018). Sheehan et al. (2025) explicitly recognize Rio de Janeiro among cities demonstrating horizontally integrated multi-hazard EWS capacity, noting that its warnings are explicitly targeted to vulnerable groups – a feature consistent with the spatial justice dimension highlighted in this note. The demonstrable life-saving effectiveness of the system – zero fatalities recorded during a severe rainfall event in March 2013 – stands as evidence of what coordinated governance across pillars can achieve. Nevertheless, persistent inequities in coverage, chronic under-investment in favela communities, and the growing intensity of extreme rainfall events driven by climate change continue to expose the limits of warning systems operating within an urban fabric shaped by decades of unplanned growth (Bartaburu, 2025). Rio's case reinforces the imperative of coupling EWS deployment with long-term urban planning instruments capable of reducing exposure at source.

1.3 Rosario, Argentina

Fig.6 Rosario's 2030 Local Climate Action Plan

Rosario, Argentina provides a compelling illustration of how risk knowledge generated through EWS processes can be progressively mainstreamed into urban planning frameworks, making it particularly relevant to the planning-centered argument of this review. The city faces compound climate hazards, most critically river flooding from the Paraná – classified as high risk by international hazard assessments – alongside extreme rainfall events, heatwaves and urban drainage failures. The EWS operates across multiple governance scales: nationally, the Servicio Meteorológico Nacional (SMN) issues colour-coded storm alerts; at the provincial level, the Autoridad Hídrica Provincial manages a telemetric hydrological network linked to a distributed mathematical model for river level forecasting; and at the municipal level, the Department of Water Management, in collaboration with the University of Rosario, has developed risk thresholds based on precipitation records to redefine flood zones and restrict construction in high-exposure areas (Hardoy & Ruete, 2013). Crucially, Sheehan et al. (2025) document Rosario's public health agency as an active contributor to EWS across multiple pillars: under Pillar 1, it maps extreme heat and zoonotic disease risk and makes climate-health epidemiological data publicly available to foster community participation in risk tracking; under Pillar 2, it monitors weather conditions in coordination with health authorities to anticipate vector-borne disease outbreaks. The municipality further published comprehensive climate risk maps in 2024, estimating that approximately 35% of the population is exposed to high risk from flooding and torrential precipitation (Municipality of Rosario, 2024). These data-driven outputs have been progressively embedded in spatial governance, informing density redistribution policies, construction restrictions along stream corridors, and nature-based solutions such as the Green Belt Project – a land-use ordinance permanently reserving peri-urban land for agroecological use that simultaneously delivers flood attenuation and urban heat island mitigation. Rosario's trajectory thus offers one of the more instructive examples available of risk intelligence – generated through EWS monitoring, community mapping and public health surveillance – feeding directly and iteratively into urban planning decisions.

4. Considerations from case studies

The urban practices presented offer multiple insights that can contribute to strengthening and furthering the development of EWS, while also surfacing limitations that warrant attention. Collectively, they provide evidence of the critical relevance of urban planning for the effectiveness of both short-term and long-term resilience and adaptation measures.

Taipei's EWS stands out for its multi-hazard integration within a single smartphone app, a design choice that reflects the inherent interconnectedness of hazards in complex metropolitan environments, where floods, windstorms, fires and infrastructure failures can cascade rapidly across an exposed urban system. Beyond its technological sophistication, the system is notable for the effective coordination of a wide range of institutional stakeholders and for its near-real-time monitoring infrastructure, which leverages IoT networks and advanced machine learning models to generate actionable forecasts at short temporal intervals. Rio de Janeiro's EWS presents two distinctive features of relevance to equity-oriented DRR. The first is a deliberately differentiated warning communication strategy: the involvement of trained community leaders as intermediaries, alongside the activation of sirens for the most imminent threats, reflects a bottom-up approach that tailors the alert system to the social fabric and spatial characteristics of the communities at risk, rather than imposing a one-size-fits-all broadcast model. The second is the explicit focus of the coupled landslide–heavy rainfall warning system on favela communities, a targeting strategy that directly addresses the most structurally vulnerable groups through site-specific, proximity-based action. Rosario’s case demonstrates the most advanced integration across all four EW4All pillars and, critically, the most developed articulation between EWS operations and urban planning and development. It features cross-sectoral and cross-level cooperation spanning municipal, provincial and national institutions; the active involvement of the University of Rosario as a strategic knowledge partner; and a central role of the public health agency, which enables the system to bridge hydrometeorological hazards – flooding and extreme heat – with disease outbreak risk, extending the EWS’s anticipatory scope beyond conventional disaster management. The entire process is designed to be transparent and participatory, engaging the community both for awareness-raising purposes and as contributors to citizens science monitoring initiatives.

Turning to the implications for urban planning, the three cases together illuminate both the current state and the potential evolution of the relationship between EWS and urban resilience governance.

Taipei's technically advanced monitoring infrastructure, deeply rooted in the spatial analysis of the urban environment, demonstrates the transformative potential of integrating real-time data systems into city operations. Yet its predominantly short-term, event-response orientation also reveals a structural limitation: EWS reach their ceiling of effectiveness when the four pillars are not scaled up and embedded in long-term climate action plans, hazard mitigation plans or climate-proof urban development and redevelopment strategies (Sheehan et al., 2025; UNDRR, 2019). Warning systems can save lives in the immediate term, but they cannot reduce the exposure that makes warnings necessary in the first place – a function that belongs, ultimately, to spatial planning.

Rio de Janeiro's case makes this tension even more explicit. Despite a well-tailored and demonstrably effective EWS, the system operates within an urban fabric fundamentally shaped by informal, unplanned development on hazard-prone slopes and floodplains. This structural condition imposes a ceiling on what any warning system can achieve and highlights the urgent need to adaptively transform those urban contexts that are recursively exposed to intensifying hazards – through managed relocation, incremental upgrading, and the integration of DRR objectives into housing and infrastructure policy (IPCC, 2022).

The Rosario case, however, offers a more generative perspective on this relationship. Its sustained and recursive cycle of risk mapping, hydrological monitoring, public health surveillance and community engagement has demonstrated that iteratively produced, multi-sectoral risk knowledge can trace persistent spatial risk patterns with sufficient resolution and credibility to directly inform planning decisions. In Rosario, this has translated into modified zoning regulations along stream corridors, construction restrictions in flood-prone areas, and the institutionalisation of nature-based solutions through binding land-use instruments such as the Green Belt Project. This trajectory suggests that when EWS are designed not merely as emergency response tools but as ongoing knowledge infrastructures embedded in urban governance, they can actively guide future development – limiting urban expansion into risk-prone areas, constraining hazard-generating land-use change, and orienting redevelopment towards more climate-resilient configurations.

Taken together, the three cases point towards a progressive understanding of EWS as a connective tissue between disaster risk management and urban planning: most effective not when they operate in isolation, but when they are institutionally anchored, spatially informed, equity-oriented and iteratively integrated into the adaptive governance processes through which cities confront – and over time reshape – their relationship with climate risk.

We can then reaffirm the importance of collection, management and representation of knowledge as operational instruments of action and decision that are as effective as possible in preventing what can be foreseen as likely (Stufano Melone & Camarda, 2025), therefore moving from analysis to planning and implementation. Moreover, the importance of land use for disaster risk reduction and climate change underlines the necessity of integrated and adaptive land use policies, that address climate-induced challenges and promote sustainable development (Okafor et al., 2025).

5. Conclusions

In this note we reviewed climate adaptation categories and dived more deeply into soft adaptation measures and their role for disaster risk reduction and urban resilience. The close, causal, relationship between urban planning practice and urban resilience was analyzed, highlighting the crucial role of urban planners in integrating adaptation across sectors and governance levels, taking up a leading role in guiding both short-term disaster risk reduction and long-term climate adaptation. We then focused on early warning systems, an effective disaster risk management measure that contributes to creating governance practices aimed at reducing impacts from extreme weather events, while contributing to strengthening long-term resilience, and institutional and community response. We proposed three exemplary cases of multi-hazard EWS in different contexts: Taipei in Taiwan, Rio de Janeiro in Brazil and Rosario in Argentina. The case studies proved the relevance of EWS in supporting urban planning practices in several ways. First, they encourage constant and updated risk assessment and monitoring, which can inform risk-informed urban policies and plans in the long-term. Second, they enable the creation of a strategic network of stakeholders relevant both for short term DRR & DRM, and for long-term climate change adaptation, including universities, civil protection, and public health authorities. Third, they support the spatial analysis of specific contexts, identifying vulnerable communities to tailor communication and emergency procedures. Finally, they stress how cross-sectoral and cross-level cooperation are crucial, posing an incentive to integrated planning and the proactive role that urban planners assume in developing urban policies towards resilient urban futures. Further research is needed to tackle the bridge between EWS and DRM measures, including the identification and operationalization of climate shelters, and the development of emergency management plans.

References

Anderson, C. C., Renaud, F. G., Hanscomb, S. & Gonzalez-Ollauri, A. (2022). Green, hybrid, or grey disaster risk reduction measures: What shapes public preferences for nature-based solutions? *Journal of Environmental Management*, *310*, 114727. https://doi.org/10.1016/j.jenvman.2022.114727

Bartaburu, X. (2025). Extreme heat, violent storms: How Rio de Janeiro is facing its new climate reality. *Mongabay*. Retrieved from: https://news.mongabay.com/2025/05/extreme-heat-violent-storms-how-rio-de-janeiro-is-facing-its-new-climate-reality/

Berkeley Earth (2026). *Global Temperature Report for 2025*. Retrieved from: https://berkeleyearth.org/global-temperature-report-for-2025/

Chang, L., Yang, M. & Chang, F. (2025). Flood resilience through hybrid deep learning: Advanced forecasting for Taipei's urban drainage system. *Journal of Environmental Management*, *379*, 124835. https://doi.org/10.1016/j.jenvman.2025.124835

Chappin, E. J. & Van Der Lei, T. (2014). Adaptation of interconnected infrastructures to climate change: A socio-technical systems perspective. *Utilities Policy*, *31*, 10-17. https://doi.org/10.1016/j.jup.2014.07.003

European Commission (n.d.). *Consequences of climate change*. https://climate.ec.europa.eu/climate-change/consequences-climate-change_en

European Environment Agency [EEA]. (2025). *Creating a catalogue of relevant adaptation options*. European Commission. Retrieved from: https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-ast/step-3-1

Global Water Partnership [GWP]. (2017). *Climate change adaptation policies (A1.03)*. Retrieved from: https://www.gwp.org/en/learn/iwrm-toolbox/The-Enabling-Environment/Policies/Climate-change-adaptation-policies/

Hardoy, J. & Ruete, R. (2013). Incorporating climate change adaptation into planning for a liveable city in Rosario, Argentina. *Environment & Urbanization*, *25* (2), 339-360. https://doi.org/10.1177/0956247813493232

Hossain, M. S., Basak, S. M., Amin, M. N., Anderson, C. C., Cremin, E. & Renaud, F. G. (2024). Social-ecological systems approach for adaptation to climate change. *Sustainable Development*, *32* (3), 2766-2778. https://doi.org/10.1002/sd.2801

Intergovernmental Panel on Climate Change [IPCC]. (2022). *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama, Eds.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Kehler, S. & Birchall, S. J. (2023). *Adaptation planning: An interdisciplinary approach to climate change risk reduction*. CMOS Bulletin SCMO. Retrieved from: https://bulletin.cmos.ca/adaptation-planning-an-interdisciplinary-approach-to-climate-change-risk-reduction/

Keith, L., Meerow, S. & Wagner, T. (2019). Planning for extreme heat: A review. *Journal of Extreme Events*, *06* (03n04), 2050003. https://doi.org/10.1142/s2345737620500037

Keith, L., Meerow, S., Jensen, L., Trego, S., Schmidt, E. L. & Berke, P. (2023a). Evaluating urban heat mitigation across networks of plans. *Journal of Planning Education and Research*, *45* (2), 427-440. https://doi.org/10.1177/0739456x231215780

Keith, L., Gabbe, C. J. & Schmidt, E. (2023b). Urban heat governance: examining the role of urban planning. *Journal of Environmental Policy & Planning*, *25* (5), 642-662. https://doi.org/10.1080/1523908X.2023.2244446

Klein, R. J. T., Midgley, G. F., Preston, B. L., Alam, M., Berkhout, F. G. H., Dow, K. & Shaw, M. R. (2014). Adaptation opportunities, constraints, and limits. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 899–943). Cambridge University Press.

Longato, D., Romanato, N. & Maragno, D. (2025). Assessing heat stress risk to support urban heat adaptation. A method applied in the Friuli Venezia Giulia region, Italy. *TeMA - Journal of Land Use, Mobility and Environment, 18* (3), 381-397. https://doi.org/10.6093/1970-9870/11738

Municipalidad de Rosario. (2021). *Plan local de acción climática Rosario 2030*. Retrieved from: https://www.rosario.gob.ar/inicio/sites/default/files/2022-06/Plan%20Local%20de%20Acci%C3%B3n%20Clima%CC%81tica%20Rosario%202030.pdf

Municipalidad de Rosario (2024). *Mapas de riesgo climático Rosario 2024*. Retrieved from: https://www.rosario.gob.ar/inicio/mapas-de-riesgo-climatico-rosario-2024

Okafor, C. L., Orebiyi, O. E., Akanmu, R. T. & Omonubi, S. O. (2025). Assessing the impacts of climate change on peri-urban land use in Nigeria. A study of Ibeju-Lekki LGA, Lagos State. *TeMA - Journal of Land Use, Mobility and Environment, 18* (3), 359-379. https://doi.org/10.6093/1970-9870/11525

Oneto, G. & Canepa, M. (2023). Addressing sustainable urban flood risk: reviewing the role and scope of theoretical models and policies. *Water Policy*, *25* (8), 797-814. https://doi.org/10.2166/wp.2023.022

Ortigao, A. (2004). Rio-Watch: the Rio de Janeiro Landslide Alarm System. *Geotechnical News*, *22* (3), 27-31.

Pennino, S. (2025). Competitive climate adaptation. Startups and urban innovation ecosystems driving climate change adaptation in cities. *TeMA - Journal of Land Use, Mobility and Environment, 18* (3), 585-592. https://doi.org/10.6093/1970-9870/12726

Sandholz, S., Lange, W. & Nehren, U. (2018). Governing green change: Ecosystem-based measures for reducing landslide risk in Rio de Janeiro. *International Journal of Disaster Risk Reduction*, *32*, 75-86. https://doi.org/10.1016/j.ijdrr.2018.01.020

Schipper, E. L. F., Revi, A., Preston, B. L., Carr, E. R., Eriksen, S. H., Fernandez-Carril, L. R., Glavovic, B. C., Hilmi, N. J. M., Ley, D., Mukerji, R., Muylaert de Araujo, M. S., Perez, R., Rose, S. K. & Singh, P. K. (2022). Climate resilient development pathways. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 2655–2807. Cambridge University Press. https://doi.org/10.1017/9781009325844.027

Sheehan, M. C., Boned-Ombuena, A., Cash-Gibson, L., Damis-Wulff, A. & Fox, M. A. (2025). *A global assessment of urban extreme weather early warning systems and public health engagement*. *Bulletin of the World Health Organization, 103* (5), 294. https://doi.org/10.2471/BLT.24.292205

Stufano Melone, M. R. & Camarda, D. (2025). Risk as a wicked problem in planning: the role of future non-knowledge*. TeMA - Journal of Land Use, Mobility and Environment, 18* (3), 457-473. https://doi.org/10.6093/1970-9870/11883

Su, Y.-S. (2016). Urban flood resilience: A chronology of policies to prevent flooding in Taipei. *International Journal of Development Research*, *6* (2), 6661-6675. Retrieved from: http://www.journalijdr.com/sites/default/files/issue-pdf/4768.pdf

Truu, M., Annus, I., Roosimägi, J., Kändler, N., Vassiljev, A. & Kaur, K. (2021). Integrated decision support system for pluvial flood-resilient spatial planning in urban areas. *Water*, *13* (23), 3340. https://doi.org/10.3390/w13233340

United Nations Framework Convention on Climate Change [UNFCCC] (n.d.). *Introduction: Adaptation and resilience*. Retrieved from: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction

United Nations Office for Disaster Risk Reduction [UNDRR] (2019). *Global Assessment Report on Disaster Risk Reduction*. Retrieved from: https://gar.undrr.org/sites/default/files/reports/2019-06/full_report.pdf

United Nations Office for Disaster Risk Reduction [UNDRR] (2020). *Disaster risk reduction and climate change adaptation: Pathways for policy coherence in Sub-Saharan Africa*. Retrieved from: https://www.undrr.org/media/47688/download?startDownload=20260417

United Nations Office for Disaster Risk Reduction [UNDRR] (2023). *Disaster risk reduction and climate change adaptation: Pathways for sustainable development and policy coherence in the Caribbean region through comprehensive risk management*. Retrieved from: https://www.undrr.org/media/90864/download?startDownload=20260420

United Nations Office for Disaster Risk Reduction [UNDRR] & CIMA Research Foundation [CIMA]. (2024). *Handbook on the Use of Risk Knowledge for Multi-Hazard Early Warning Systems*. Retrieved from: https://www.cimafoundation.org/wp-content/ uploads/2024/10/CIMA-Handbook-EW4ALL-2024.pdf

United Nations Office for Disaster Risk Reduction [UNDRR], & World Meteorological Organization [WMO]. (2025). *Global Status of Multi-Hazard Early Warning Systems*. Retrieved from: https://library.wmo.int/viewer/69684/download?file=Global-Status-of-MHEWS-2025-Report_en.pdf&type=pdf&navigator=1

World Meteorological Organization [WMO] (2022). *Early warnings for all: Executive action plan 2023–2027*. Retrieved from: https://library.wmo.int/viewer/58209/download?file=Executive_Action_Plan_en.pdf&type=pdf&navigator=1

Image Sources

Fig.1: Schipper, E. L. F., Revi, A., Preston, B. L., Carr, E. R., Eriksen, S. H., Fernandez-Carril, L. R., Glavovic, B. C., Hilmi, N. J. M., Ley, D., Mukerji, R., Muylaert de Araujo, M. S., Perez, R., Rose, S. K. & Singh, P. K. (2022). Climate resilient development pathways. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 2655–2807). Cambridge University Press. https://doi.org/10.1017/9781009325844.027. Retrieved from: https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-18/;

Fig.2: World Meteorological Organization [WMO]. (2022). *Early warnings for all: Executive action plan 2023–2027*. https://library.wmo.int/viewer/58209/download?file=Executive_Action_Plan_en.pdf&type=pdf&navigator=1. Retrieved from: https://www.un.org/en/climatechange/early-warnings-for-all;

Fig.3: World Meteorological Organisation [WMO]. Retrieved from: https://wmo.int/content/early-warnings-all;

Fig.4: Central Weather Administration. Retrieved from: https://www.cwa.gov.tw/V8/E/S/eservice/app/app_w.html;

Fig.5: Center of Operations Rio. Retrieved from: https://aplicativo.cocr.com.br/apresentacao_cor_en;

Fig.6: Rosario Municipality. Retrieved from: https://www.rosario.gob.ar/web/sites/default/files/plan_local_de_accion_ climatica _rosario_2030_0.pdf.

Author's profile

Stella Pennino

She is an engineer and Ph.D. candidate in Civil Systems Engineering at the Department of Civil, Building and Environmental Engineering of the University of Naples Federico II. Her research focuses on adaptation to climate change in urban systems, with particular attention to risk assessment, urban resilience, and local climate governance processes. She investigates how planning tools, policy frameworks, and innovative approaches can enhance the capacity of public administrations to address climate-related risks and support sustainable urban transitions. Her work aims to contribute to the integration of climate adaptation and sustainability principles into urban planning and decision-making processes.