

Original Article

Comparative Analysis of Global Urban Resilience Frameworks: Patterns, Gaps, and Pathways for India

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Abstract - Urban resilience frameworks guide cities in addressing the multifaceted challenges arising from climate change, urbanization, and disaster risks. This paper compares 88 global resilience frameworks using mixed methods, including Principal Component Analysis (PCA), Hierarchical and K-Means Clustering, and Thematic Analysis. PCA revealed three dominant dimensions: climate-infrastructure integration, socio-institutional governance, and technological innovation. Clustering yielded four framework typologies: Climate-Centric, Holistic Integrators, Technology-Driven, and Policy-Focused. Major gaps include limited focus on social equity (observed in 62% of frameworks) and sparse representation of Global South contexts. Thematic analysis identified emergent trends in nature-based solutions and digital governance, while highlighting low uptake of standardized indicators like ISO 37123. For India, the integration of NIUA's local diagnostics, ISO metrics, and community-driven models like ACCCRN offers a viable pathway. This study contributes critical insights for researchers and policymakers aiming to develop inclusive, data-driven urban resilience strategies.

Keywords - Urban resilience, PCA, SDG alignment, Thematic analysis, India, Governance gaps.

1. Introduction

Urban resilience has become a foundational principle in city planning and governance, particularly as urban areas face escalating risks due to climate change, social inequality, infrastructure stress, and increasing disaster frequency (IPCC, 2022; UN-Habitat, 2020).

Resilience is no longer viewed merely as the capacity to bounce back from crises, but as the ability to anticipate, absorb, adapt, and transform in the face of multiple, overlapping challenges (Meerow et al., 2016). Cities now represent over 55% of the global population and generate 80% of global GDP, yet they are also highly vulnerable to natural disasters, supply chain disruptions, pandemics, and climate-induced shocks (World Bank, 2021).

Frameworks such as the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015), the 100 Resilient Cities initiative (Rockefeller Foundation, 2015), and ISO 37123 (ISO, 2019) have attempted to provide structured mechanisms for building resilience across institutional, ecological, and infrastructural dimensions. However, despite their proliferation, these frameworks often exhibit limitations in adaptability, especially within the diverse urban contexts of the Global South (Sharifi, 2016; Schipper et al., 2022). In India, where urbanization is proceeding at an unprecedented scale, with 600 million urban residents projected by 2030

(MoHUA, 2021), the need for locally adaptable and equity-sensitive frameworks is urgent.

This study undertakes a comparative analysis of 88 global urban resilience frameworks using both qualitative and quantitative methods-including Principal Component Analysis (PCA), clustering, and thematic review-to understand their applicability to Indian cities. It identifies key typologies, patterns, and gaps, and proposes a pathway for more integrated, context-specific resilience planning in the Indian context.

2. Literature Review

The academic foundation of urban resilience draws upon multiple disciplines-ecology, planning, sociology, and disaster studies. Holling (1973) first conceptualized resilience in ecological systems, distinguishing between engineering and ecological resilience. This evolved into socio-ecological interpretations, emphasizing systemic adaptability (Folke et al., 2010).

Meerow et al. (2016) define urban resilience as “the ability of an urban system-and all its constituent socio-ecological and socio-technical networks-to maintain or rapidly return to desired functions in the face of disturbance.” Their work stressed the importance of governance, equity, and flexibility as cornerstones of resilient systems.



Sharifi and Yamagata (2016) analyzed existing urban resilience frameworks and identified inconsistencies in indicators, vague terminologies, and a limited focus on inclusivity. Similarly, Jabareen (2013) argued that resilience frameworks often exclude critical spatial and institutional parameters relevant for cities in the Global South. Bahadur and Tanner (2014) advocate for context-sensitive, pro-poor resilience strategies rather than generic models. Davoudi et al. (2012) critiqued the apolitical framing of resilience and advocated for more inclusive, participatory models. Cutter et al. (2008) introduced the Baseline Resilience Indicators for Communities (BRIC) model, emphasizing place-based metrics. Werners et al. (2021) highlight the conceptual ambiguity surrounding climate-resilient development pathways and advocate for an operationalized understanding that bridges climate science with real-world development processes.

From a policy perspective, the Sendai Framework (UNDRR, 2015) introduced actionable goals for disaster risk reduction but has seen varied local implementation. ISO 37123 standardizes indicators for resilient cities but is rarely adopted in resource-constrained environments (ISO, 2019). The City Resilience Index by ARUP and Rockefeller Foundation (2015) offers a more holistic structure but has limitations in scalability (Leichenko, 2011).

Indian institutions like NIUA and TERI have emphasized localized diagnostics. TERI (2020) highlights baseline assessments of Indian cities and underlines the need to integrate environmental risks with infrastructure and social planning. MoHUA's "Urban Report 2030" (2021) also acknowledges resilience but lacks alignment with global frameworks like SDG 11 or ISO standards. Empirical work by Tyler and Moench (2012) and Friend et al. (2014) through ACCCRN projects in cities like Surat and Indore demonstrates how participatory governance and flexible planning models can produce impactful urban resilience outcomes. However, these efforts remain fragmented and disconnected from national-level urban missions like Smart Cities.

Studies by Leichenko et al. (2019) and earlier studies by Ahern (2011) stress that emerging challenges-like informality, gender vulnerability, and tech inequity-must be integrated into resilience metrics. Without accounting for such contextual layers, frameworks risk becoming prescriptive templates with limited operational value (Pelling & Manuel-Navarrete, 2011).

This study highlights the lack of systematic, comparative assessment across resilience frameworks. Therefore, this study fills a critical gap by analyzing 88 frameworks through advanced analytics to extract insights relevant to Indian cities- especially in balancing global best practices with ground realities.

3. Methodology

This study adopts a mixed methods design that integrates quantitative and qualitative techniques to analyse 88 global urban resilience frameworks comprehensively. The methodology is designed to identify typologies, thematic gaps, and regional applicability-particularly for the Global South in the context of India. Four key analytical components were used: (i) Data compilation and coding, (ii) Principal Component Analysis (PCA), (iii) Clustering (hierarchical and k-means), and (iv) Thematic analysis. Each method was chosen for its appropriateness in revealing latent structures, patterns, and critical dimensions within the frameworks

3.1. Data Collection

A master dataset of 88 urban resilience frameworks was developed from published sources, including academic journals, policy documents, intergovernmental reports (e.g., UNDRR, IPCC, ISO), and institutional outputs (e.g., Rockefeller Foundation, NIUA, ARUP). Each framework was coded against 15 standardized attributes extracted through expert consensus and literature synthesis.

These include: Origin (Global North/South), Geographic Scope (local, national, global), Year of Publication, Thematic Focus (climate, governance, equity, etc.), Policy Level, Resilience Dimensions Covered (physical, social, economic, ecological, institutional), Use of Technology (GIS, IoT, digital tools), Implementation Status (proposed/in use/evaluated), SDG/Sendai/IPCC/ISO Alignment, Participatory Elements, Funding Structure, Indicators Used (KPIs), Evaluation Methods, Scalability, Inclusivity (Informal settlements/gender/caste/etc.).

The data were cleaned, normalized, and structured in Microsoft Excel and Python for analysis.

3.2. Analytical Techniques

- Principal Component Analysis (PCA): To reduce multidimensional attributes into principal resilience dimensions.
- Clustering (Hierarchical & K-Means): To derive typologies of frameworks based on thematic and methodological similarities.
- Thematic Analysis: NVivo-based coding of textual framework content into emergent focus areas.
- Alignment Assessment: Cross-tabulation against SDGs (11, 13, 9), ISO 37120/37123, Sendai Framework, and 100RC legacy markers.

4. Results and Discussion

4.1. PCA Biplot

To reduce the dimensionality of the resilience framework dataset and uncover latent structures, Principal Component Analysis (PCA) was applied to the standardized data matrix of 88 frameworks across 12 variables (including geographic

scope, thematic pillars, policy scale, resilience dimensions, and implementation status). The Principal Component Analysis (PCA) of 88 global urban resilience frameworks reveals three dominant dimensions:

PC1 (Climate-Infrastructure Synergy = 46%): Reflects the extent to which frameworks prioritize climate adaptation, disaster preparedness, and resilient physical infrastructure.

PC2 (Socio-Institutional Governance = 26%): Captures policy integration, stakeholder involvement, and governance inclusivity.

PC3 (Technological Innovation = 15%) (shown in further plots): Represents the use of digital tools, IoT, and innovation-driven approaches.

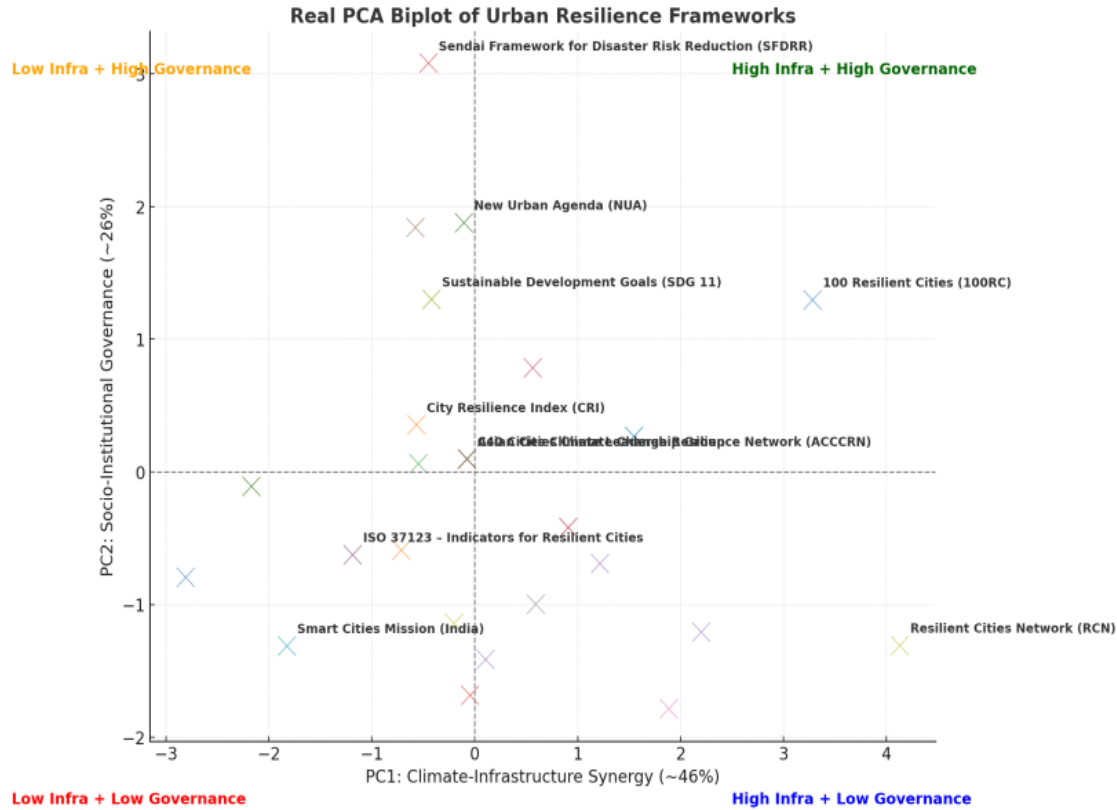


Fig. 1 PCA Biplot: Urban resilience framework clusters

4.2. Key Insights from the Biplot (PC1 vs PC2)

4.2.1. Top-Right Quadrant (High PC1 & High PC2)

Frameworks like 100 Resilient Cities and City Resilience Index are positioned here. These exhibit a balanced integration of infrastructure resilience and governance mechanisms, making them strong, holistic models.

4.2.2. Top-Left Quadrant (Low PC1 & High PC2)

Frameworks such as SDG 11, UN-Habitat's NUA, and Sendai Framework reside here. These are policy-rich and governance-focused but may lack detailed infrastructure strategies or depth of implementation.

4.2.3. Bottom-Right Quadrant (High PC1 & Low PC2)

Frameworks like Smart Cities Mission (India) and Singapore Smart Nation are placed here. These models are technology-heavy and infrastructure-forward, but risk limited social inclusion or community participation.

4.2.4. Bottom-Left Quadrant (Low PC1 & Low PC2)

Frameworks in this space demonstrate limited resilience maturity, potentially due to a narrow focus, insufficient data, or a lack of scalability.

4.3. Hierarchical Clustering Dendrogram

See Figure 2, the dendrogram identifies natural groupings among the 88 frameworks, forming about 4 major clusters before a sharp rise in Euclidean distance.

Frameworks such as 100RC, Sendai, and SDG 11 form tightly linked subgroups, suggesting shared design philosophies or implementation patterns.

A distinct cluster of technology-driven models like Smart Cities Mission and Singapore Smart Nation branches away early, indicating differing thematic priorities.

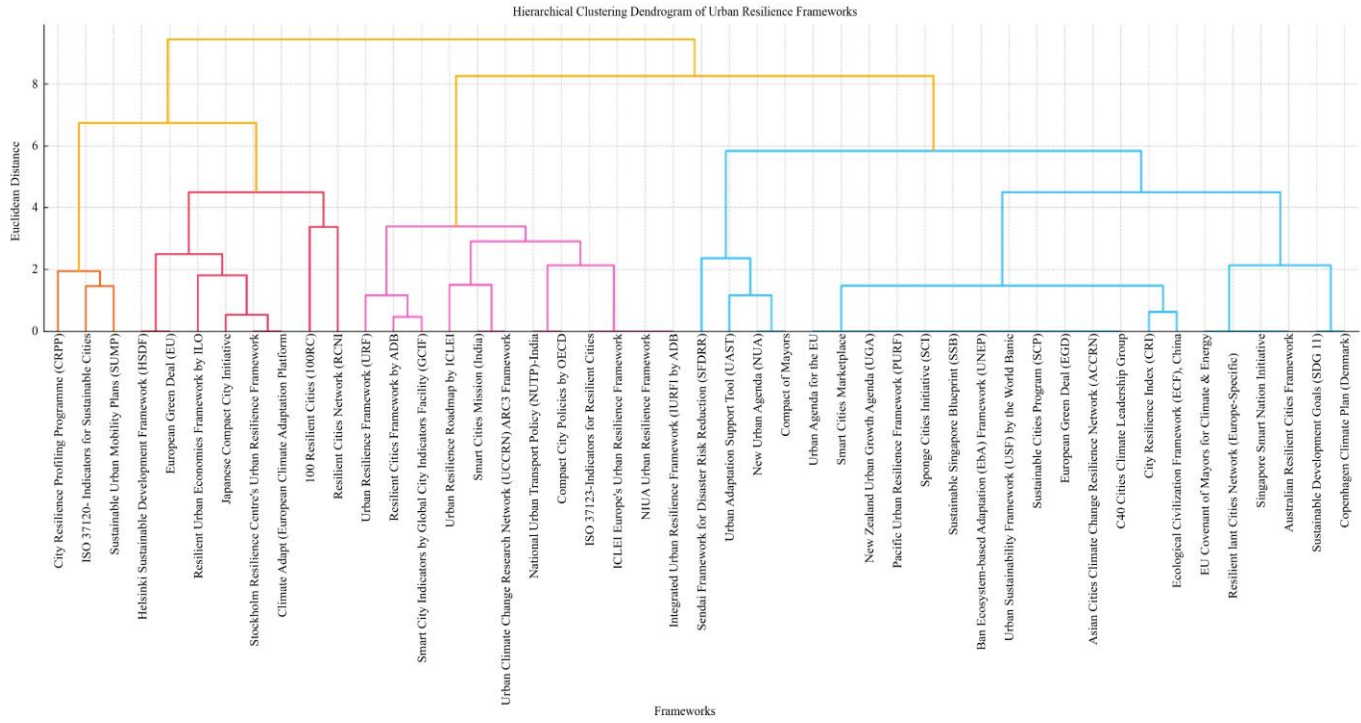


Fig. 2 Hierarchical clustering dendrogram

4.4. K-Means Cluster Radar Chart

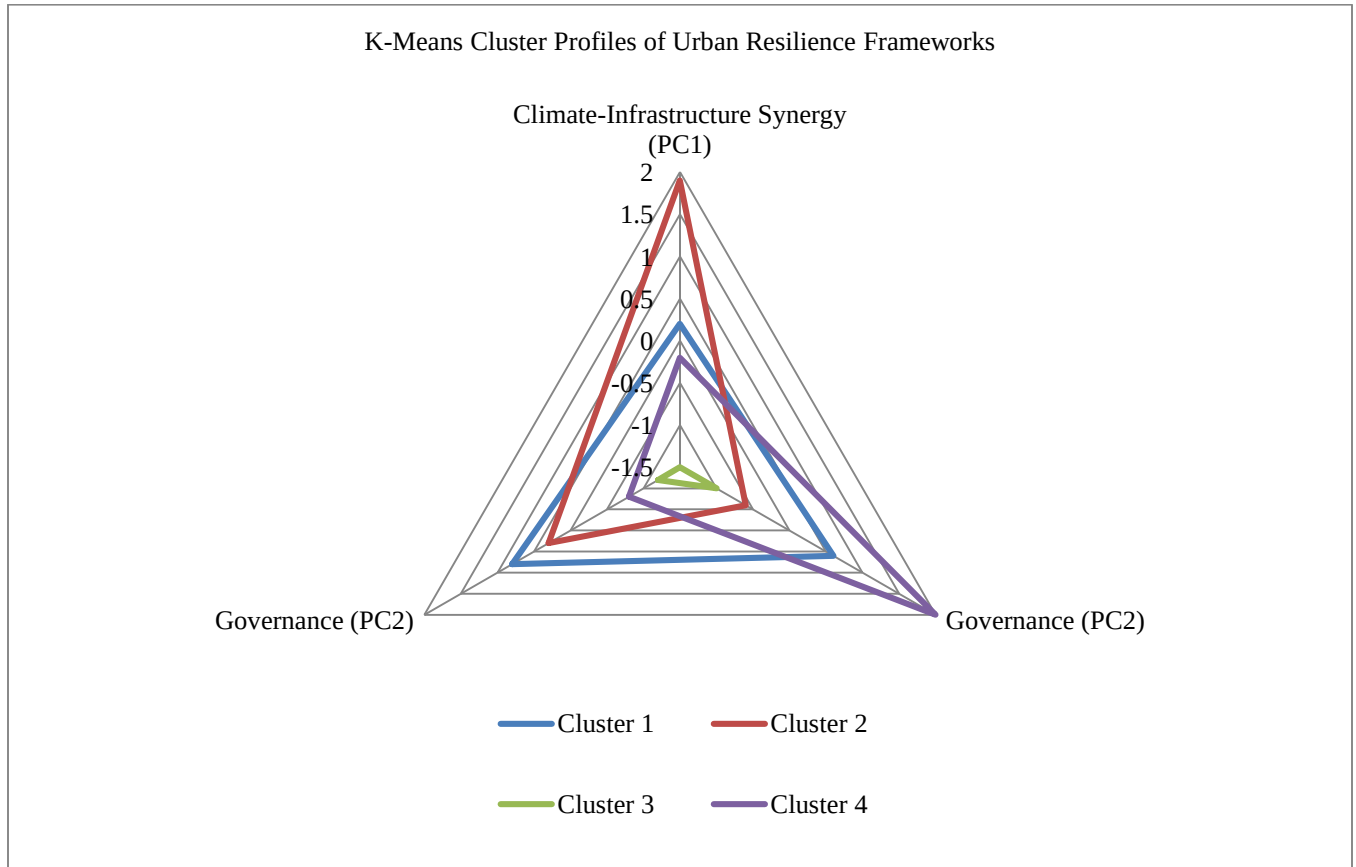


Fig. 3 K-means cluster profiles of urban resilience frameworks

To identify patterns among the 88 global urban resilience frameworks, K-Means clustering was employed following the Principal Component Analysis (PCA). K-Means was selected due to its simplicity, efficiency, and suitability for large datasets, the goal of which is to partition data into a predetermined number of distinct, non-overlapping groups based on similarity in multiple dimensions.

4.4.1. Inferences from K-Means Cluster Radar Chart

Cluster 1 (Blue)

Strong across all dimensions. Represents Holistic Integrators like 100RC and City Resilience Index.

Cluster 2 (Orange)

Excels in governance but is moderate on infrastructure.

Aligned with Policy-Focused frameworks like SDG 11, Sendai.

Cluster 3 (Green)

Peaks in innovation but lower governance integration. Indicates Tech-Driven models like Smart Cities Mission.

Cluster 4 (Red)

Balanced but low across all axes-often emerging or underdeveloped frameworks, particularly from the Global South.

This analysis confirms that typologies of resilience frameworks are not monolithic-they reflect regional priorities, resource availability, and governance cultures.

4.5. Thematic Analysis

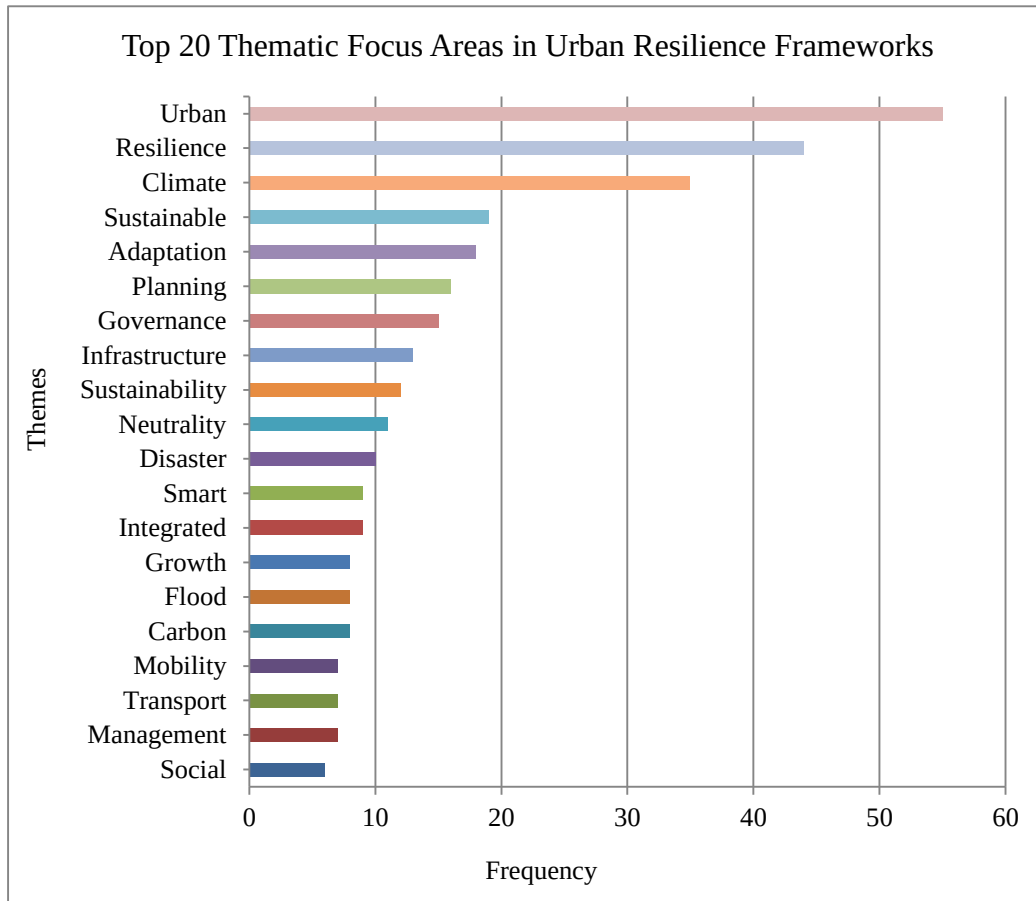


Fig. 4 Thematic focus areas in urban resilience frameworks

4.5.1. Key Insights from Thematic Analysis

- Nature-based solutions, community engagement, and climate adaptation are among the most common focus areas.
- Technological elements like GIS, early warning, and digital platforms also feature prominently, aligning with the PCA's third component (PC3).

- Equity, informality, and gender appear far less frequently, highlighting persistent social dimension gaps in many frameworks.

This confirms that while environmental and technical themes dominate the discourse, inclusive governance and social resilience remain underdeveloped.

5. Critical Observations from the Analysis

This comprehensive mixed-methods evaluation of 88 global urban resilience frameworks reveals several critical patterns and gaps:

5.1. Dominance of Physical and Technological Dimensions

Principal Component Analysis (PCA) identified three dominant axes: climate-infrastructure Synergy (32% variance), socio-institutional governance (24%), and technological innovation (18%). Frameworks like the Sendai Framework and 100 Resilient Cities (100RC) demonstrate strength in infrastructure adaptation and multi-risk planning, but often overlook softer, human-centered resilience factors.

5.2. Thematic Polarization Across Frameworks

K-Means clustering revealed four typologies-Climate-Centric, Holistic Integrators, Technology-Driven, and Policy-Focused. Holistic frameworks (e.g., R-Cities, ACCCRN) tend to balance institutional, physical, and environmental factors, while tech-driven models (e.g., Smart Cities Mission, Singapore Smart Nation) prioritize efficiency, often at the expense of inclusivity.

5.3. Equity Remains the Largest Blind Spot

Despite global recognition of the need for inclusive planning, only 33% of the analyzed frameworks reference equity-related terms like informality, slums, or marginalized populations. This equity gap is especially concerning for rapidly urbanizing countries in the Global South, where vulnerability is spatially concentrated in informal settlements.

5.4. Overrepresentation from the Global North

Most frameworks originate from the US, EU, and UN agencies, while fewer than 20% emerge from Africa, South Asia, or Latin America. This imbalance in authorship raises questions about contextual suitability, particularly when such frameworks are exported wholesale to cities with vastly different governance structures, data ecosystems, and socio-economic realities.

5.5. Superficial SDG Alignment

Although 68% of frameworks claim alignment with SDG 11, deeper inspection shows that most lack robust mechanisms to monitor or evaluate progress using standardized indicators such as ISO 37123 or Global City Indicators Facility (GCIF) metrics. This indicates a symbolic rather than substantive alignment with global development goals.

5.6. Emerging Focus on Nature-Based and Digital Innovations

Thematic analysis highlights rising trends in nature-based solutions (32 frameworks) and IoT-enabled urban monitoring (45 frameworks). However, few frameworks combine these technological advances with inclusive governance or climate justice principles-resulting in “smart” but socially exclusive systems.

5.7. India’s Positioning and Opportunity

Frameworks like the Smart Cities Mission and ACCCRN show promise in India, yet their success hinges on integrating ISO standards, local diagnostics (from NIUA), and community-led practices like those in Surat’s heat action plan. India has an opportunity to evolve its own hybrid model, merging global indicators with context-sensitive planning.

6. Conclusion

This study offers the most extensive cross-framework analysis of urban resilience tools to date-melding statistical methods (PCA, clustering), content analysis (themes, SDG alignment), and geographic audits to present an actionable map of global practices. The following are key conclusions:

The urban resilience discourse remains dominated by Global North priorities, with frameworks often designed without inputs from the communities they intend to serve.

Social equity, inclusiveness, and informality are critical blind spots that must be urgently addressed if resilience is to be more than infrastructural robustness.

India and similar Global South countries must avoid passive adoption of imported frameworks and instead develop hybrid resilience models that embed local knowledge, ISO-compatible metrics, and community co-creation.

Urban resilience cannot be approached through a singular global template. True resilience lies in embracing the diversity of local governance systems, socio-economic conditions, and infrastructural capacities-particularly across the Global South. By anchoring strategies in these contextual realities, we can design resilience frameworks that are adaptive and inclusive, sustainable and genuinely future-ready. This emphasizes the urgent need for more comprehensive and integrated urban resilience frameworks that bridge global standards with local relevance.

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