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Abstract

Sustainable settlement design frameworks (SSDFs) have received limited scholarly attention regarding their integration of disaster risk reduction (DRR) and community involvement (CI) dimensions, despite the compounding pressures of rapid urbanization, climate change, and population growth. This study aims to analyze how strategies of DRR and CI are represented in existing SSDFs, an area that remains underexplored in the literature. A deductive content analysis was conducted on 10 selected SSDFs, applying Dimitrova and Snair's integrated DRR framework and Arnstein's ladder of citizen participation as analytical lenses. The analysis yielded 231 codes organized into 11 thematic categories. Inter-coder reliability was established through Krippendorff's alpha ($\alpha \geq 0.95$ across all coder pairs). Results reveal that DRR strategies are unevenly distributed across the examined SSDFs: hazard corrective (Haz-cor) and hazard prospective (Haz-pro) strategies are most prevalent, whereas vulnerability prospective (Vul-pro), vulnerability compensatory (Vul-com), and exposure prospective (Exp-pro) strategies are significantly underrepresented. Community involvement is predominantly operationalized through tokenistic participation (consultation and informing) rather than genuine citizen empowerment. Based on these findings, we propose an integrated model that embeds DRR and community participation into sustainable settlement design through a systems-thinking approach, incorporating balanced compensatory, prospective, and corrective outlooks toward hazard, exposure, and vulnerability, alongside temporal-scale considerations. The proposed model offers a conceptual framework for urban planners, researchers, and policymakers seeking to strengthen the resilience and sustainability of settlement design.

Keywords: Disaster risk mitigation; Climate adaptation; Sustainable urban design; Policy Analysis; Resilience building; Systems thinking

1 Introduction

Strengthening sustainable settlement design frameworks (SSDFs) is crucial for addressing the interconnected challenges of rapid urbanization, population growth,

and climate change adaptation [1]. By 2050, approximately 1.2 billion additional residents are expected to be accommodated in urban areas, with the majority concentrated in the Global South [2]. Urbanization continues to expand into nature reserves, natural drainage systems, and geologically complex regions, disrupting socio-ecological balance and altering settlement patterns [3]. Multiple SSDFs have been developed to address these challenges, including eco-design approaches [4], eco-city models emphasizing ecological preservation [5], the Isulabantu (ISU) Toolkit for in-situ slum upgrading [6], Participatory Action Research (PAR) frameworks supporting transdisciplinary collaboration [7], the Resilient and Green Human Settlement (RGHS) Framework for climate change adaptation [8], and the Deprived Framework for low-to-middle-income households [9].

Notable examples of urban planning innovation include the Tapiola Garden City [10], Otaniemi High-tech Campus [11], and EcoVIIKI [12] from the Finnish urban planning tradition, which have introduced sustainable solutions such as green fingers, small-scale solar energy production, and stormwater management [13]. Globally, emerging settlement concepts including global cities, oasis cities, green settlements, smart cities, and knowledge cities are bringing both new opportunities and challenges to urban development [14].

Despite these diverse efforts, SSDF research has predominantly focused on ecological buildings, urban sustainability, and the built environment, assessing dimensions such as energy consumption, land-use patterns, affordable housing, waste management, drainage, street networking, public spaces, and mobility [15]. These contributions align with Sustainable Development Goal (SDG) 11, which focuses on making cities inclusive, safe, resilient, and sustainable [16]. However, limited scholarly attention has been directed toward SSDF integration with hazard exposure including landslides, earthquakes, slope stability, fire, flood, and safety provision creating a critical gap that constrains these frameworks from achieving their full potential. Despite significant capacity to reduce hazard risk through participatory approaches, SSDFs remain largely unexplored within the field of DRR, which fundamentally depends on the intersection of hazards with exposure, vulnerability, adaptive capacity, and risk. This gap is particularly urgent because urban settlements are projected to house 60% of the global population by 2030 [15]. Furthermore, in

2024, urban areas faced high risks from climate-induced hazards resulting in economic losses of approximately USD 241.95 billion [2].

The need for integrating DRR and climate change action through participatory measures in development planning frameworks is well established [17]. In response, this paper aims to elucidate the representation of DRR and community involvement aspects in current SSDFs through content analysis, applying the integrated DRR framework [18] and Arnstein's [19] ladder of citizen participation. The research questions guiding this study are:

RQ1. How are the key strategies of DRR represented in existing SSDFs through their guidelines and policies?

RQ2. How do various SSDFs engage with community involvement aspects?

The novelty of this research lies in the proposed integrated model for sustainable settlement design that synthesizes DRR strategies and CI dimensions. This model incorporates exposure, vulnerability, risk, and community participation into SSDFs, contributing to an action-oriented paradigm shift in transforming design, development, and governance. The paper is structured as follows: Section 2 presents the theoretical analysis of the DRR framework and Arnstein's ladder theory; Section 3 explains the content analysis methodology; Section 4 addresses the research questions through 231 codes and 11 themes; Section 5 provides a discussion and introduces the proposed model; and Section 6 presents conclusions with future directions and limitations.

2 Theoretical Background

SSDFs have captured significant attention in urban planning, policymaking, and sustainable development practice. Over the past decade, growing bodies of research in urban development have highlighted the role of SSDFs in driving forward sustainable innovation [20], ecological models [21], and settlement transformation [22]. Mainstream studies have primarily focused on the application of SSDFs in informal settlement upgrading [23], housing development, urban green spaces [24], and socio-ecological relationships [25]. While this body of work demonstrates the

breadth of SSDF applications, it has focused on a limited number of dominant sectors, limiting the overall understanding of SSDF diversity and impact.

SSDFs incorporate urban design principles such as urban green infrastructure, community-based disaster preparedness, improved building codes and standards, enhanced environmental quality, and reduced dependency on fossil fuels [26]. Climate-focused urban design strategies include sustainable urban drainage systems (SUDS) [27], blue-green infrastructure (BGI) [28], and green infrastructure (GI) [29], where mixed use, density, walkability, energy efficiency, urban greening, low greenhouse gas emissions, and connectivity are common to resilient, sustainable, and new urbanist approaches. However, these strategies can be severely disrupted during disasters, impacting day-to-day community functioning and resulting in human, economic, and environmental losses. The 2030 Agenda for Sustainable Development [30] emphasizes the need to prevent and reduce existing disaster risk, address underlying risk drivers, increase preparedness, and strengthen capacities. Unfortunately, poor governance and lack of political will to invest in preparedness frameworks remain widespread, as resources continue to be disproportionately allocated to disaster response and recovery [31]. Prioritizing the systematization of DRR strategies across three core components hazard, exposure, and vulnerability is essential for understanding community urban resilience to natural disasters [32].

2.1 Strategies of Disaster Risk Reduction

The United Nations Sendai Framework for Disaster Risk Reduction (SFDRR) aims to prevent new and reduce existing disaster risk through the implementation of integrated and inclusive measures that address hazard, exposure, and vulnerability while increasing preparedness for response and recovery [33]. Traditional DRR strategies have relied on structural, techno-centric, resource- and capital-intensive measures that are often disruptive to ecological processes, further increasing community vulnerability and exposure at the grassroots level [34].

In this study, the novel integrated DRR framework proposed by Dimitrova and Snair [18] is employed as it provides a systematic approach to categorizing and elucidating DRR strategies. This framework has previously been applied in understanding trends and gaps in the 2019 Cities100 report [35] and calculating the distribution of city-level

DRR interventions by World Bank income categories [18]. The framework segregates nine DRR categories organized across three dimensions hazard, exposure, and vulnerability and three temporal orientations prospective (preventing future risk), corrective (reducing existing risk), and compensatory (building resilience) consistent with the established conceptualization of risk as a function of hazard, exposure, and vulnerability [36, 37]. Accordingly, deductive conceptual content analysis was applied to identify which DRR strategies are over- and underrepresented in existing SSDFs, providing insights into where future efforts should be directed for more balanced and equitable DRR implementation.

2.2 Arnstein's Ladder of Citizen Participation

This study employs Arnstein's [19] ladder of citizen participation, which delineates stages of civic engagement through three tiers: non-participation (manipulation and therapy), degrees of tokenism (informing, consultation, placation), and degrees of citizen power (partnership, delegated power, and citizen control). The framework posits that genuine participation occurs when communities are partners in decision-making, and it has been extensively applied in assessing participatory processes in developing countries, including post-disaster recovery and relocation projects [38, 39], housing construction [40], community participation in climate change adaptation [41], citizen participation in smart cities [42], and participatory mapping in flood-prone areas [43].

Our study operationalizes Arnstein's ladder to evaluate how CI is represented in SSDFs, as it serves as a robust tool for evaluating existing power relationships in participatory processes and provides nuanced understanding of how power dynamics operate across different study contexts [44, 45]. The ladder theory enables movement beyond general participation metrics, grasping how CI is represented, under what pretexts communities are engaged, and the extent to which genuine empowerment and power transfer are achieved [45]. Given that frameworks often claim citizen involvement through pro-active participation, yet inadequate infrastructure and resources to support meaningful community participation persist [46, 47], this analytical lens is particularly appropriate.

For the purposes of this study, the non-participation rungs (manipulation and therapy) were excluded from the analytical framework, as they did not serve the study's purpose of analyzing constructive CI aspects. The remaining levels tokenism (informing, consultation, placation) and citizen power (partnership, delegated power, citizen control) were operationalized as community participation (Com-par) and community power (Com-pow) respectively.

3 Methodology

3.1 Content Analysis as a Research Method

Content analysis is defined as "any technique for making inferences by systematically and objectively identifying special characteristics of messages" [48]. This method adapts to different document types, including public policies, guidelines, and frameworks, allowing rigorous documentation analysis while ensuring validity and reliability across multidisciplinary fields [49]. Content analysis has previously been employed in qualitative analyses of frameworks, including smart city performance measurement [50], big data in smart cities [51], and urban planning principles [21]. It has also been applied to examine concepts [52], definitions, and emerging trends [53], generating condensed descriptions of phenomena particularly where limited literature has been explored [54].

Our content analysis employed a relational approach, focusing not on the frequency of specific words or phrases but rather on the presence and nature of information addressing DRR or CI. Following deductive content analysis, categories and themes were derived from existing theoretical knowledge specifically the DRR framework and Arnstein's ladder theory. We adopted latent content analysis to interpret the underlying meaning of the text rather than surface-level features, consistent with the study's analytical depth and aims [55].

3.2 Sampling and Screening

A systematic search was conducted using Web of Science and Scopus databases with the following keywords: "Sustainable AND settlement AND (framework OR method* OR tool* OR guideline*) community, disaster." The search was limited to

publications from 2009 to 2025. This 16-year timeframe captures the most significant developments and practical applications of SSDFs, particularly the post-Sendai Framework period (after 2015), when DRR integration gained critical importance.

The initial search yielded 53 documents. After removing duplicates and applying exclusion criteria, which eliminated papers focused on refugee settlement, tourism destinations, micro-credits in resettlement sites, medical education, or rural settlement, and retaining only English-language publications, the number of qualifying articles was reduced to 13. Only frameworks and toolkits used in real-world settlement design scenarios were included. After screening titles and abstracts, 8 articles qualified for analysis, supplemented by 2 guideline documents from grey literature (Smart City Guidelines, [56]; PMAY-Urban 2.0, [57], yielding a total of 10 documents for complete analysis. Table 1 presents the selected documents.

Table 1 Documents selected for content analysis

S.No.	Level	Document Type	Published By	Focus Area	Reference with year
01	National	Guideline	Ministry of Urban Affairs, India	Affordable housing for urban poor	[57]
02	Regional	Toolkit	Engineering Sustainability Journal	Upgrading informal settlement	[6]
03	Regional	Framework	Global Challenges Journal	Housing intervention for low-income settlement	[7]
04	Regional	Framework	Informes de la Construcción	Urban sustainability	[4]
05	Regional	Framework	Energies Journal	Sustainable urban development	[5]
06	Regional	Framework	Journal for Urban Planning & Development	Sustainability of human settlement	[58]

07	International	Framework	Comp. Env. & Urban Systems	Urban inhabitants in low middle income groups	[9]
08	Regional	Framework	United Nations-Habitat	Green development	[8]
09	International	Framework	Cities Journal	System of systems approach	[59]
10	National	Guideline	Ministry of Urban Affairs, India	Smart urban solutions	[56]

3.3 Unit of Analysis and Coding Procedure

The unit of analysis consisted of sentences or text segments within the selected SSDFs identified as addressing concepts from the DRR framework or Arnstein's ladder theory. Each qualifying segment was assigned one or more codes from a predefined codebook, following established deductive content analysis procedures [60, 61]. The codebook (Table 2) was developed deductively, deriving codes directly from the DRR framework and Arnstein's ladder theory. Three independent coders two disaster management professionals and one architecture and planning expert were engaged in the coding process. The coders worked independently using MAXQDA 2018 software, assigning codes to paragraphs based on a thorough reading of the SSDF content and the codebook. Subsequently, coders compared their results, discussed paragraphs coded similarly and differently, and resolved disagreements through open discussion.

Table 2 Codebook for DRR and CI aspects

DRR Dimension	Thematic Categories	Definition
Hazard	• Prospective (Haz-pro)	Investment in recognizing, reducing, preventing, and accommodating measures to reduce future hazard by minimizing potential damage before a hazard event occurs
	• Corrective (Haz-cor)	Mitigating current hazard by minimizing, avoiding, and correcting measures to reduce existing impact through alternate measures

	• Compensatory (Haz-com)	Strengthening resilience to hazard by upgrading, improving, adapting, preserving, and promoting social, environmental, and risk-informed urban development
Vulnerability	• Prospective (Vul-pro)	Preventing future vulnerability from occurring by encouraging, enabling, and establishing accessible measures
	• Corrective (Vul-cor)	Reducing current vulnerabilities through prioritizing, addressing, and modifying actions
	• Compensatory (Vul-com)	Increasing resilience of vulnerable groups by strengthening the capacity of agencies
Exposure	• Prospective (Exp-pro)	Preventing future exposure by investing in resilient actions
	• Corrective (Exp-cor)	Reducing current exposure by replacing and eliminating existing exposure
	• Compensatory (Exp-com)	Increasing resilience to exposure through long-term measures
Community Involvement	• Participation (Com-par)	Community involvement through informing, consultation, and placation (tokenism)
	• Power (Com-pow)	Community decision-making power through partnership, delegated power, and citizen control

3.4 Inter-Coder Reliability

To establish coding reliability, 231 paragraphs were coded under 11 categories by three independent coders. The probability of two judges assigning codes to the same category by chance was calculated using the binomial probability, given in Eq. (1):

$$P(k\ successes) = \left\{\frac{\mathrm{N!}}{\mathrm{k!\times(N-k)!}}\right\} \times \{p^k \times (1-p)^{N-k}\} \quad (1)$$

Here, N is the total number of paragraph that were coded, k is the total number of matches between judges and *p* is probability of two judges assigning the same theme. Thus, the probability for pairwise agreement by two judges will be $p = \frac{1}{11} = 0.090$, and $N = 231$ and the probabilities are 225, 221 and 223 matches respectively, can be represented as follows:

Coder *1* and *2:* $P(225) = \left\{\frac{231!}{225!\times(231-225)!}\right\} \times \left(\frac{1}{11}\right)^{225} \times \left(1-\frac{1}{11}\right)^{231-225} = (5.43 \times 10^{-224})$

Coder *1* and *3:* $P(221) = \left\{\frac{231!}{221!\times(231-221)!}\right\} \times \left(\frac{1}{11}\right)^{221} \times \left(1-\frac{1}{11}\right)^{231-221} = (2.68 \times 10^{-214})$

Coder *2* and *3:* $P(223) = \left\{\frac{231!}{223!\times(231-223)!}\right\} \times \left(\frac{1}{11}\right)^{223} \times \left(1-\frac{1}{11}\right)^{231-223} = (4.88 \times 10^{-219})$

The probability of the results obtained by luck is extremely low. These results are quantified by using normal approximation to the binomial distribution. We have applied the Z-score to calculate the probability of obtaining 221 of 231 matches (lowest match) or more matches using the Eq. (2):

$$z = \frac{K - E_K}{\sqrt{np(1-p)}} \quad (2)$$

Where E_k (expected number of matches); $E_k = 231 \times \left(\frac{1}{11}\right) = 20.9$

The result is placed to the Z – score formula for the coders with the lowest agreement (coder 1 and 3):

$$z = \frac{221-20.9}{\sqrt{231\times\left(\frac{1}{11}\right)\times\left(\frac{10}{11}\right)}} = 45.80$$

The pairwise agreement levels were Coder 1 and 2 (225 matches), Coder 1 and 3 (221 matches), and Coder 2 and 3 (223 matches). For the coder pair with the lowest agreement (Coders 1 and 3, with 221 of 231 matches), the Z-score was calculated as 45.80, indicating that the probability of obtaining this level of agreement by chance is significantly low ($p < 0.001$).

Krippendorff's alpha (α) was used to assess inter-rater reliability, as it accommodates multiple raters, varying sample sizes, and missing data [62]. This can be calculated by using the formula for an ordinal probability given in Eq. (3):

$$\alpha = 1 - \frac{Do}{De} \quad (3)$$

Where, D_o stands for observation disagreement, *α* (Alpha) is the number of matches between the coders and D_e is the expected disagreement (Krippendorff, 2019). When this formula is applied to each pairwise agreement, it calculates the probability that two judges will assign a code to the same paragraph by using the assigned codebook. Given the unit of analysis paragraphs, codebook and three independent coders of this

study, Kalpha coefficient's threshold for satisfactory level is 0.80 as suggested by Krippendorff.

Coder *1* and *2*

$$\alpha = 1 - \frac{D_o}{D_e} = 0.97$$

Coder *1* and *3*

$$\alpha = 1 - \frac{D_o}{D_e} = 0.95$$

Coder *2* and *3*

$$\alpha = 1 - \frac{D_o}{D_e} = 0.96$$

The web-based K-Alpha Calculator [63] yielded the following pairwise reliability coefficients: Coder 1 and 2 (α = 0.97), Coder 1 and 3 (α = 0.95), and Coder 2 and 3 (α = 0.96). All values exceed the satisfactory threshold of α ≥ 0.80 recommended by [49], indicating near-perfect agreement among coders.

4 Results

The content analysis of 10 SSDFs (7 frameworks, 2 guidelines, and 1 toolkit) yielded 231 codes organized into 11 thematic categories through deductive coding derived from the DRR framework and Arnstein's ladder theory. Table 3 presents the thematic categories, total codes, and representative examples. This section presents the findings organized by the two research questions.

Table 3 Content coded from SSDFs using DRR framework and Arnstein's ladder theory

Theme	Category	Codes	Representative Examples
Hazard	Prospective (Haz-pro)	29	e.g., investment in local renewable energy, sustainable architecture, national building codes, disaster-resilient construction, climate-responsive design, earthquake-resistant construction

	Corrective (Haz-cor)	32	e.g., minimal non-renewable resource use, fire-resistant design, hazard self-assessment, flood catchments, mangrove buffer zones, building simulation, smart metering
	Compensatory (Haz-com)	20	e.g., community skill building, urban agriculture, health risk assessment, good governance, walkable localities, risk-based planning, mixed land use
Vulnerability	Prospective (Vul-pro)	16	e.g., local business creation, real-time monitoring, housing vouchers, hygienic living spaces, community centers, home-based businesses, livelihood support
	Corrective (Vul-cor)	23	e.g., disability ramps, alternate land for hazardous slums, affordable rental housing, pedestrian-friendly pathways, social audit, gender-responsive provisions
	Compensatory (Vul-com)	14	e.g., intersectional gender analysis, fund mobilization, co-production practices, community enumeration, sex-disaggregated data
Exposure	Prospective (Exp-pro)	13	e.g., geo-tagging of houses, adequate green cover, affordable rental housing, awareness activities, stormwater drainage
	Corrective (Exp-cor)	26	e.g., energy-efficient climate-resilient settlements, green infrastructure through climate-smart technologies, climate-proofing of public infrastructure
	Compensatory (Exp-com)	16	e.g., agricultural mosaic planning, early warning systems, lifecycle approach, systems thinking, nature-based programs, area-based development plans
Community Involvement	Community Participation (Com-par)	24	e.g., community capacity building, participatory mapping, co-design, focus groups, self-assessment, community meetings, local knowledge
	Community Power (Com-pow)	18	e.g., community-led upgrading, community-led resilience building, citizen-driven solutions, grassroots leadership and decision making, community empowerment

4.1 Representation of DRR in SSDFs (RQ1)

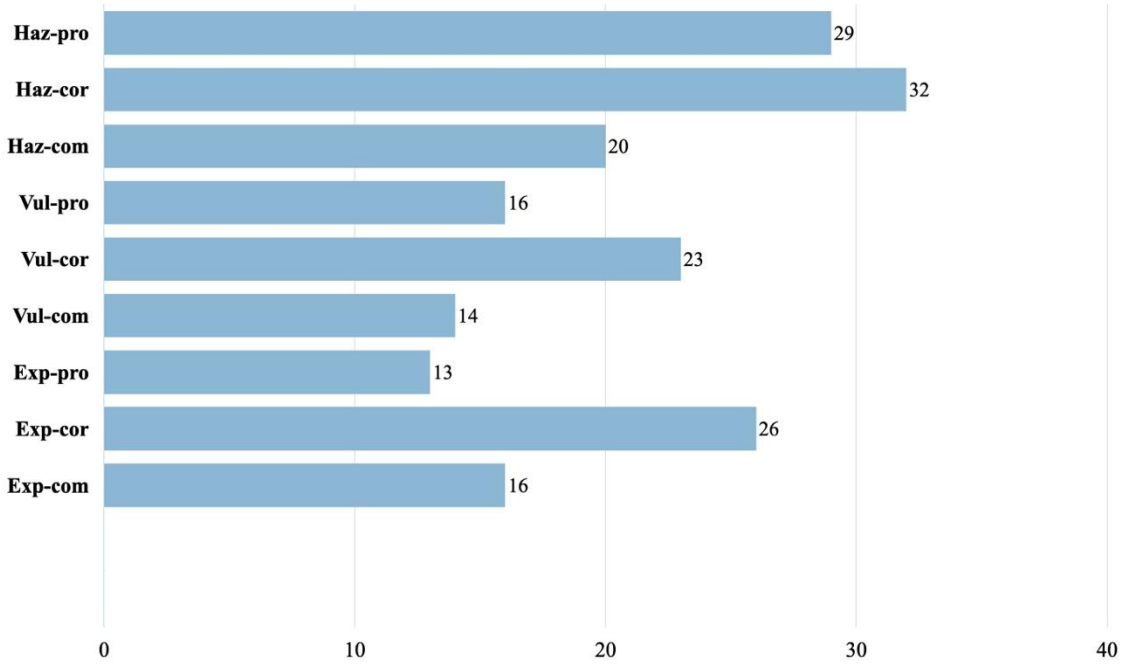


Fig. 1 Representation of the total number of DRR strategies represented in the SSDF

In **Error! Reference source not found.**, hazard corrective (Haz-cor) emerged as the most prevalent DRR category, addressed by 9 out of 10 SSDFs with 32 total codes. This category encompasses reduction, avoidance and recycling measures like preventive action of fire-safe housing design in informal settlement, promoting wastewater recycling in EcoCity and retrofitting for area improvement applied in smart city. While exposure compensatory (Exp-com) strategies aim to increase resilience through long-term disaster risk governance via regulation and policy integration, their representation across SSDFs is fragmented and inconsistent addressed by 8 out of 10 SSDFs with 16 total codes. For example, Finland's EcoCity action plan was applied in Libya through Finnish-Libyan Cooperation, but the high social and political instability in Libya left the implementation of phases II and III on standby. Eco-design highlights environmental conservation but lacks the capacity to absorb, adapt, and recover from shocks or stresses. Smart City guidelines reduce exposure to administrative bottlenecks but risk treating symptoms of social systems, often focusing on surface-level problems by ticking the checklist and ignoring the existing system of grassroots development.

Hazard prospective (Haz-pro) was also represented in 9 of 10 SSDFs with 29 codes, focused on investment in renewable energy, solar panel installation, low-carbon

concrete, early warning systems, and eco-friendly building materials. For instance, the ISU toolkit promotes early warning through social media or message alerts, an approach whose reliability during active hazard events has been questioned by research on forecasting performance metrics, including hits, missed events, and false alarms [64]. These measures acknowledge that hazard impacts can be minimized through sustainable design practices during the planning phase. Urban areas are mainly defined by technology, investment opportunities, and the knowledge economy. This narrow view can ignore disaster risk governance, complex social and political issues. Guidelines such as PMAY and Smart City have invested Haz-pro measures because they involve resource-centric interventions that are more visible to the public; moreover leaders prefer prevention activities and consider them valuable for their constituents, rather than addressing deeper systemic issues such as poverty, governance biases (discrimination, transparency, and accountability), and top-down planning, which require sustained behavioral change.

In contrast, vulnerability compensatory (Vul-com) was addressed by 7 of 10 SSDFs with 14 codes. This category focuses on building resilience among particularly vulnerable groups, including the urban poor, low-to-middle-income groups (LMIG), and economically weaker sections (EWS), and people with disability through fund mobilization, compensation mechanisms, and mitigation of inequality and power imbalances. The low representation reflects structural neglect of vulnerable populations such as urban migrants, homeless individuals, construction workers, and women in construction, thereby perpetuating urban inequality. Addressing the root cause of vulnerability requires systemic investigation to identify the fundamental, underlying factor that makes the community susceptible to hazard, triggering deep-seated socio-political and economic conditions.

Exposure prospective (Exp-pro) was the least represented category being highly inconsistent, addressed by only 6 of 10 SSDFs with 13 codes, encompassing measures aimed at preventing future exposure through investment in resilient actions such as adequate green cover, affordable rental housing, and awareness activities. Without long-term investment in resilient actions, the connection between urban areas and their supporting ecosystems weakens.

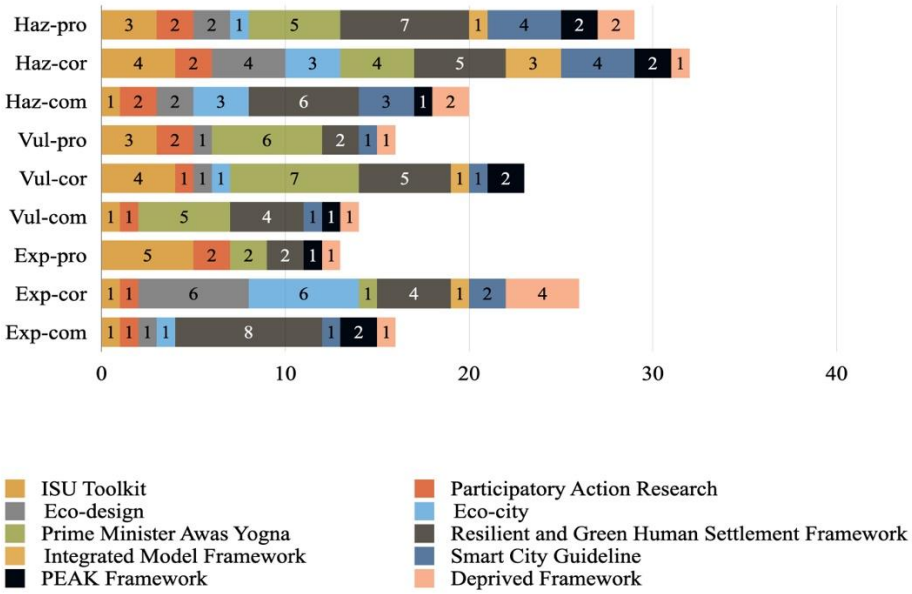


Fig. 2 Stacked bar chart showing DRR categories across individual SSDFs

The cross-framework analysis Fig. ***2*** further reveals that the DRR strategies, hazard corrective and prospective (Haz-cor, Haz-pro) were present across 10 SSDFs, reflecting that hazard mitigation is the most visible and consistently addressed dimension. Vulnerability prospective (Vul-pro) and vulnerability compensatory (Vul-com) appeared in 7 SSDFs, whereas exposure prospective (Exp-pro) was present in only 6 SSDFs. This imbalance suggests that while prospective vulnerability measures are addressed, such as real-time monitoring, thematic workshops, and green recovery, the root causes of vulnerability remain inadequately tackled, highlighting a significant gap. Frameworks such as Eco-design, and EcoCity do not represent Vul-com, indicating a lack of interdisciplinary understanding of institutional complexity and context-specific socio-political conditions. Overall, corrective actions are overrepresented relative to prospective and compensatory measures, likely because corrective interventions are short-term, more visible, and require less strategic planning and political will than long-term resilience building [4, 56].

4.2 Representation of Community Involvement in SSDFs (RQ 2)

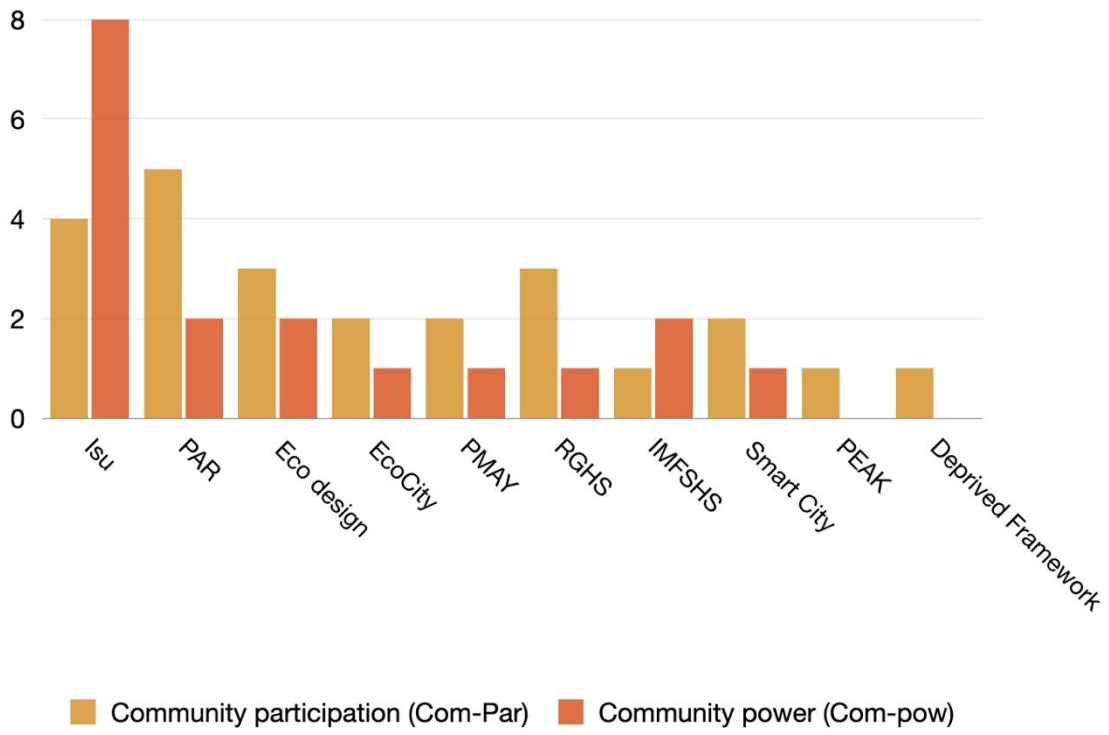


Fig. 3 Grouped bar chart showing Com-par and Com-pow across each SSDF

In Fig. ***3***, community participation (Com-par) and community power (Com-pow) were represented in 9 and 8 of the 10 SSDFs, totaling 24 and 18 codes, respectively. Applying Arnstein's ladder theory of public participation in SSDF shows the inclination towards degree of tokenism enabling the community to follow externally designed interventions for data collection and project intervention. Com-par, encompassing consultation, informing, and placation, was operationalized through diverse mechanisms; the IMFSHS positioned community attitudes as central to overcoming threats to community sustainability [58], while the Smart City guidelines established Resident Welfare Associations, community-based groups, slum dweller associations, and e-groups providing online feedback, consultation, and voting rights (Ministry of Urban Development 2015) [56]. While these platforms provide opportunities for vulnerable groups to participate, questions remain regarding the transparency and effectiveness of these tokenistic participation mechanisms. However, keeping the community engaged can be quite challenging, as they must take time out of their daily activities and may see it as an additional task. Until SSDF takes community participation through livelihood-generation activities by improving financial services to increase market opportunities, the willingness to participate and stay engaged in the project will remain low.

Despite being represented in 8 SSDFs, Com-pow showed a lower frequency with 18 codes, concentrated primarily in the ISU toolkit, PAR, and Eco-design frameworks, where community upgrading, community prototyping, and neighborhood approaches were implemented. Arnstein highlights delegated power, observed in SSDF, but such delegation does not extend to broader planning. Such community-driven frameworks have been applied in informal settlements, fostering self-sufficiency and empowerment. Notably, the Deprived and PEAK frameworks showed no community power dimensions. This gap demonstrates that mere community participation does not automatically translate into community empowerment or resilience-building. Redundancy was observed in community involvement, with limited passive participation and no proactive empowerment measures, a pattern that often leads to conflicts of interest and poor implementation when top-down approaches persist. When communities residing in the informal sector assume greater roles and responsibilities, engagement becomes more meaningful and fosters a sense of ownership. Scholars have criticized conventional participatory practices that adopt a top-down approach as ineffective. Instead, they advocate for inviting communities to initiate, develop, and implement their own plans through transdisciplinary measures, which give control over decision-making and make participation more legitimate.

5 Discussion

This content analysis reveals how SSDFs address DRR strategies and CI in urban contexts. Aggregating codes into broader themes, the dominant DRR representations include hazard prospective (Haz-pro), hazard corrective (Haz-cor) and exposure corrective (Exp-cor). Several critical insights emerge from these findings.

First, Haz-cor strategies include reactive responses to current and immediate threats, and Haz-pro strategies include valuable investments in passive solar design for temperature mitigation [65], greenhouse gas reduction through fossil-fuel-free zones [66], and Passivhaus-standard buildings [67]. While these measures represent meaningful integration of urban design and DRR, the critical gap lies in the notable absence of investment in addressing daily-life vulnerability and adaptation, while urban funding continues to prioritize command-and-control systems and information and communication technologies.

Second, the results demonstrate that corrective measures are overrepresented relative to prospective and compensatory measures across all three dimensions (hazard, vulnerability, exposure). Corrective interventions tend to be short-term and relatively straightforward to implement. The underrepresentation of prospective and compensatory actions suggests that building long-term resilience requires more strategic planning and political will than current frameworks typically accommodate [4, 56]. The limited representation of Exp-com, despite its importance as a long-term resilience strategy, combined with its inherent limitations as a reactive rather than preventive approach, remains a critical weakness threatening settlement design's long-term resilience.

Third, regarding community involvement, while grassroots and participatory approaches reveal the importance of CI, state-driven and techno-managerial frameworks often confine communities to consultative, passive-recipient, or data-provider roles, where decision-making power remains vested in bureaucratic structures. The PEAK and Deprived frameworks showed particularly low community participation, potentially because communities may resist change and urban design projects require significant skilled expertise. Communities' place attachment and identity deserve greater attention, as settlement areas can provide feelings of pride and well-being [68]. The failure to transition from consultative tokenism to genuine empowerment represents a significant barrier to effective SSDF operationalization [69]. While grassroots frameworks have shown that identity and endurance play a key role in sustaining settlement designs through bottom-up approaches [53], achieving such empowerment at scale remains challenging.

Lastly, the prevalence of Exp-com strategies reflects an emphasis on technology-driven and regulatory approaches to disaster risk. Smart city initiatives leverage diverse real-time data to investigate urban affairs and predict development scenarios from traffic bottlenecks to flooding patterns [70] yet cities are primarily viewed through technological lenses with command-and-control protocols that often fail to address disaster risk governance and the socio-political dynamics among competing stakeholders. Consequently, frameworks rarely address how exposure evolves over time, instead remaining as static snapshots that inherently weaken urban system resilience.

5.1 Proposed Integrated Model: Strengthening SSDFs through Systems Thinking

Based on the empirical findings, we propose an integrated model Fig. ***4*** that embeds DRR and CI within SSDFs through a systems thinking approach. The model recognizes the interconnectedness of various urban components affordable housing, street networking, water quality, accessible public health, education, public transport, drainage, waste management, open spaces, economic opportunities, and community participation—and how interventions in one domain affect others. The model comprises five interconnected pillars:

Community Involvement. The ISU toolkit [6] and PAR [7] demonstrate how community participation through focus group discussions, participatory mapping, transect walks, solution-oriented workshops, settlement profiling, and incremental upgrading using recycled materials can drive effective settlement design. Stakeholder mapping is crucial, and the planning team should comprise designers, architects, urban planners, engineers, and local leaders. Meaningful community engagement based on mutual benefit minimizes risk, enhances project sustainability, and fosters empowerment and local ownership.

DRR Integration. Risk can be reduced by addressing hazard, exposure, and vulnerability through balanced prospective, corrective, and compensatory approaches. The RGHS framework [8] demonstrates how DRR can be integrated in urban planning through urban renewal, green urbanism, stakeholder engagement in hazard and vulnerability analysis, and incorporation of nature-based solutions. DRR integration encompasses four processes: (a) risk identification, involving community-led hazard assessment; (b) risk assessment, employing multidisciplinary inputs including community attitudes, health, and environmental processes; (c) risk mitigation, through retrofitting, redevelopment, and sustainable infrastructure; and (d) preparedness, strengthening community-based response capacities.

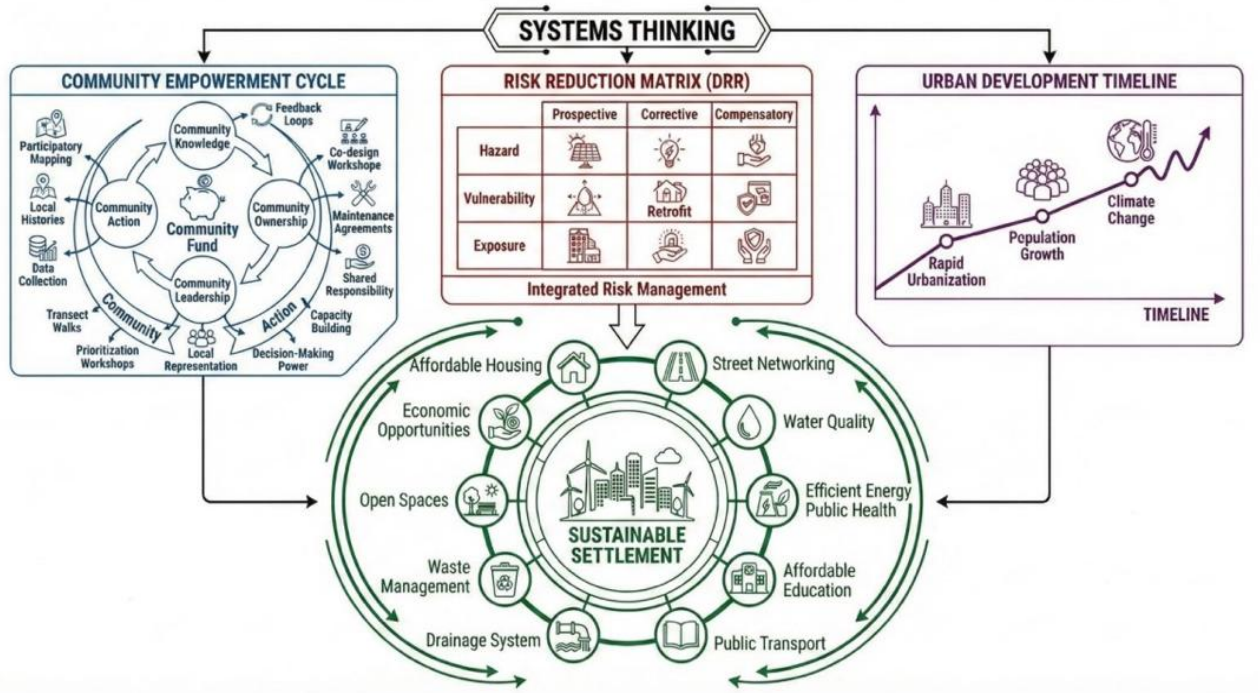


Fig. 4 Proposed integrated model diagram for SSDFs through Systems Thinking

Bottom-Up Approaches. Bottom-up strategies—including observation, transect walks, in-depth interviews, group discussions, collaborative mind mapping, and priority mapping—focus on user experiences of housing and environmental management [6]. PAR demonstrated that bottom-up methods in the initial stages help establish local participants' perspectives and priorities regarding housing-related health hazards [7]. Community participation in SSDFs should be decentralized to empower local populations [71].

Temporal Scale. Urban theory and planning have gradually evolved from welfare economics and urban growth machines toward resilience, smart cities, and urban green spaces [72]. Sustainable transformation involves systematic elements aligned with temporal scales accounting for economic shifts (rapid urbanization, migration), social transformations (informal settlement growth, demographic changes), and environmental pressures (climate change, deforestation) [72]. Urban development is shifting from a "build and forget" model to a life-cycle model focused on reducing emissions and creating hazard-resilient occupancy over 20-year horizons [53]. Climate change is reshaping urban development across multiple temporal scales, particularly for coastal and low-lying cities [73].

Systems Interconnectedness. The model highlights how each component of settlement design is interconnected within an urban system. Urban expansion into wetland areas can be addressed through DRR integration via land-use planning, risk assessment, hazard mapping, and local knowledge. Strategic interventions such as enforcing building codes or providing alternative livelihoods through adaptive learning systems can break negative cycles of risk accumulation.

5.2 Applications of the Proposed Model

The integrated model serves multiple stakeholder groups. For urban planners, it provides a tool for understanding DRR in settlement design through local context-sensitivity, risk assessment, early warning system planning, preparedness planning, infrastructure standards, community engagement, and environmental management. For researchers, the model facilitates collaboration among urban planners, architects, DRR experts, and engineers to explore intersectionality and develop comprehensive resilient infrastructure, applications, and training programs. For policymakers, the model supports policy formulation by aligning DRR and SSDF strategies toward policy coherence and improved urban resilience.

6 Conclusion

This paper, using content analysis has examined the current state of SSDFs, revealing significant gaps in how DRR and CI are addressed. While settlement design is widely adopted through eco-design, eco-city frameworks, smart city guidelines, and the ISU toolkit, scholarly discourse remains concentrated in dominant domains. This study provides a unique contribution by integrating DRR strategies for strengthening SSDFs in urban contexts, drawing on 10 frameworks spanning global to regional contexts including India (Delhi), South Africa (Durban), Spain (Vallbona), Finland (Helsinki), and the Philippines (Manila).

The key contributions are threefold. First, it demonstrates that DRR strategies are unevenly distributed across SSDFs, with hazard corrective and hazard prospective measures receiving disproportionate attention while vulnerability prospective, vulnerability compensatory, and exposure prospective measures remain underrepresented. Second, it reveals that community involvement is predominantly

tokenistic rather than empowering, with significant variation in the depth of power transfer. Third, the proposed integrated model addresses these gaps through a systems thinking approach, incorporating DRR and CI simultaneously for local adaptation.

As climate-induced hazards accelerate, the integration of DRR and CI aspects becomes increasingly critical. The transformative potential of SSDFs requires a paradigm shift from treating DRR and CI as separate entities to recognizing them as functional units, balancing investment between corrective and long-term resilience building amid changing risk landscapes and rapid urbanization. Only through such integration can SSDFs be strengthened to build more resilient infrastructure and communities.

The study is subject to certain limitations. The analysis focuses on documents published between 2009 and 2025 and may overlook relevant reports and policy documents outside this timeframe. Future research should incorporate primary data to investigate state-level bylaws, zonal plans, and national building codes to further strengthen SSDF development. Additionally, operationalizing the proposed model through measurable indicators and testing in real-world scenarios represents a critical next step for advancing integrated disaster risk governance in sustainable settlement design.

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