

From Buildings to Neighborhoods: Upscaling Smartness Assessment for Enhanced Sustainability

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Abstract— This study embarks on an innovative exploration of upscaling the smartness assessment of buildings to the neighborhood scale, aiming to bridge the gap in sustainability evaluation practices. With urban development rapidly advancing, the imperative to extend the assessment of individual building units to encompass entire neighborhoods becomes crucial for achieving broader sustainability goals. Through a comprehensive review of 18 seminal papers, the research identifies existing methodologies for assessing the sustainability of buildings and examines their applicability and challenges in scaling to larger urban areas. Key findings reveal that 44% of the reviewed frameworks emphasize technological integration and stakeholder engagement, while 17% address the complexity of urban infrastructure interdependencies. Central to this investigation are the multifaceted obstacles encountered, including the integration of diverse building types, variance in technological adoption, and the complexity of urban infrastructure interdependencies. To navigate these challenges, the study proposes a novel framework designed to guide the upscaling process. This framework emphasizes the importance of interoperability, community engagement, and adaptive governance structures, aiming to facilitate a cohesive approach to smartness assessment. By setting forth a strategic pathway, the research aspires to enhance the accuracy and efficacy of sustainability evaluations at the neighborhood level, contributing to the broader objective of creating more sustainable, resilient, and smart urban environments.

Keywords: *Smart Readiness Indicator (SRI), Smart Grids, Neighborhood Scale, Sustainability.*

I. INTRODUCTION

The research for sustainable urban development has increasingly recognized the importance of integrating 'smartness' in buildings and extending it to entire neighborhoods. This shift towards smart cities, where information and communication technologies (ICT) are woven into urban fabrics, aims to optimize resource utilization and improve urban life quality through smarter energy management, enhanced environmental resilience, and improved public services [1], [2]. However, the leap from individual buildings to the broader neighborhood context introduces complexities, such as varied building functions, technological heterogeneity, and the intricate web of urban infrastructure [2], [3]. This research aims to bridge the existing gap in sustainability evaluation by upscaling the smartness assessment from the building level to the neighborhood scale, responding to the pressing need for a comprehensive framework that addresses these complexities.

As urban development accelerates, the necessity of broadening the scope of smartness assessments to include entire neighborhoods is paramount for realizing wider sustainability ambitions. This study poses a critical inquiry into the current methodologies employed for smartness

quantification, aiming to enhance the sustainability assessment at the neighborhood scale [3]. Urban areas, the epicentres of sustainability challenges and opportunities, necessitate robust, adaptable assessment methodologies that align with the dynamism and diversity of modern urban landscapes.

The novelty of this work lies in its comprehensive approach to addressing the gap in existing sustainability evaluation practices. While considerable efforts have been made to assess the smartness of individual buildings, there is a distinct lack of methodologies that effectively extend this assessment to the neighborhood level. This research is pioneering in its aim to investigate the need of developing a holistic framework that not only incorporates individual building assessments but also integrates these evaluations within the broader context of urban neighborhoods. This framework should address the multidimensional nature of urban ecosystems, encompassing technological integration, environmental sustainability, and social well-being.

The necessity for this review is further underscored by the rapid urbanization and the pressing need for sustainable urban planning. Urban areas are growing at an unprecedented rate, and with this growth comes increased pressure on resources and infrastructure. Traditional sustainability assessment tools are insufficient to address the complexities of modern urban neighborhoods, leading to a gap in effective sustainability planning. This research fills this gap by providing a detailed analysis of current methodologies, identifying their limitations, and proposing a comprehensive framework for neighborhood-scale smartness assessment.

Adopting a systematic literature review methodology, this paper scrutinizes a spectrum of existing approaches to smartness quantification at the neighborhood level. Through an analytical review of eighteen seminal papers, this study identifies emerging themes, methodological innovations, and the principal challenges encountered in existing practices. These encompass the development of innovative assessment frameworks, insights into methodological advancements for smart technology integration, and the overarching implications for urban planning and policy [1], [4].

Central to our examination is the Smart Readiness Indicator (SRI) scheme, incorporated with renowned sustainability certifications such as LEED, BREEAM, DGNB, and GRESB, to forge a comprehensive framework that encapsulates all aspects of neighborhood smartness. This framework aspires to surmount the numerous challenges identified, including the diversity of building types, the variance in technological uptake, and the complexity of urban infrastructural interdependencies [2], [4].

By consolidating insights from the systematic literature review with the theoretical foundations of the SRI and other

sustainability certifications, this research delineates a strategic pathway towards refining sustainability evaluations at the neighborhood level. It seeks to enrich the discussion on creating sustainable, resilient, and intelligent urban environments, offering invaluable insights for urban planners, policymakers, and stakeholders engaged in smart city initiatives [5], [6].

II. THEMATIC ANALYSIS AND SYNTHESIS FROM THE SYSTEMATIC LITERATURE REVIEW

The systematic literature review central to this study explores the evolution of smartness from the scale of buildings to neighborhoods, highlighting the critical path toward sustainable urban development. The objective is to dissect the multidimensional aspects of urban smartness, including technological integration, sustainability practices, and the social fabric that underlines urban ecosystems. This section delineates the thematic analysis conducted on selected literature, emphasizing four main themes: Indicators of Smartness, Challenges in Upscaling, Proposed Frameworks, and Case Studies. This approach not only provided a lens to view the current state of research but also identified gaps and opportunities for future investigation.

Through this comprehensive review, the study aims to construct a nuanced understanding of the factors that contribute to the effective implementation of smart technologies at a broader urban scale. By systematically categorizing and analyzing the literature, the review highlights the intricate interplay between technological advancements and socio-environmental factors in achieving sustainable urban development. It identifies the strengths and limitations of current methodologies, offering a critical assessment of their applicability to neighborhood-level assessments. Additionally, this thematic analysis underscores the need for adaptive frameworks that can accommodate the diverse and dynamic nature of urban environments. By bridging the gap between theory and practice, the study seeks to inform future research and policy-making, ultimately contributing to the creation of more resilient, inclusive, and smart urban communities.

A. Literature Search and Selection

The selection process was guided by stringent inclusion criteria designed to capture comprehensive insights into the assessment of smartness and sustainability at the neighborhood level. These criteria focused on studies contributing to the discourse on smartness indicators, challenges in upscaling from individual buildings to broader urban areas, innovative frameworks for operationalizing smartness at the neighborhood scale, and empirical case studies demonstrating the practical application of such frameworks. The utilization of reference management facilitated an organized and efficient review, ensuring a broad yet focused collection of relevant scholarly work.

A multi-phase selection process was employed, starting with a broad search of databases using keywords such as "smart cities," "sustainability assessment," "neighborhood smartness," and "urban development frameworks." The initial search yielded over 200 articles, which were then screened for relevance based on their abstracts and titles. Articles that did not focus on neighborhood-level assessments or lacked empirical data were excluded. The

remaining 50 articles underwent a full-text review, resulting in the final selection of 18 seminal papers that met the inclusion criteria. This rigorous selection process ensured that the reviewed literature provided a comprehensive and in-depth understanding of the current state of neighborhood smartness assessments.

B. Thematic Contributions

A deep dive into the selected literature illuminated four recurrent themes, encapsulating the challenges and innovations in the field of urban smartness and sustainability:

1. Indicators of Smartness

This theme underscores the necessity of developing robust, actionable indicators to quantify and evaluate the implementation and impact of smart technologies within urban settings. Papers [5], [8], [9], [12] delve into various aspects of smartness indicators, from environmental sustainability metrics and energy efficiency to technological adoption and community well-being. These contributions highlight the complexity of accurately measuring urban smartness, underscoring the need for indicators that are both comprehensive and adaptable to diverse urban contexts.

Furthermore, the development of these indicators must consider both quantitative and qualitative data to capture the full scope of smartness, including user satisfaction and socio-economic benefits. Effective indicators must be flexible enough to evolve with technological advancements and changing urban dynamics, providing a reliable basis for policy-making and strategic planning. This comprehensive approach ensures that smart city initiatives are not only technologically advanced but also socially inclusive and environmentally sustainable.

2. Challenges in Upscaling

Transitioning from the granularity of building-specific assessments to the complexity of neighborhood-wide evaluations introduces a myriad of challenges [3], [4], [15]. These studies articulate the methodological hurdles, including the variance in technological infrastructure, the integration of diverse building functions, and the dynamic interplay of urban systems. Such challenges necessitate the development of scalable, flexible tools capable of accommodating the multifaceted nature of urban environments.

Moreover, addressing these challenges requires a multi-disciplinary approach, integrating insights from urban planning, engineering, sociology, and economics. The literature emphasizes the importance of creating interoperable systems that can seamlessly integrate data from various sources, enhancing the accuracy and efficiency of smartness assessments. Additionally, overcoming the challenges of upscaling involves ensuring that technological solutions are cost-effective and accessible to all segments of the population, thereby promoting equity in smart urban development.

3. Proposed Frameworks

Innovative frameworks and models emerge as solutions to the identified challenges, offering structured methodologies for enhancing urban smartness at the neighborhood level [1],[2], [5], [7], [11], [13], [16], [18]. These frameworks propose holistic approaches to integrating smartness indicators, addressing technological disparities, and fostering stakeholder engagement. Their contributions

are pivotal in providing a blueprint for operationalizing smart and sustainable urban development across diverse contexts.

The proposed frameworks often incorporate real-time data analytics, predictive modelling, and participatory planning processes to ensure that smart city initiatives are responsive to current and future needs. By fostering collaboration among stakeholders, including government agencies, private sector partners, and local communities, these frameworks aim to create a shared vision for sustainable urban development. The incorporation of feedback loops within these frameworks allows for continuous improvement and adaptation, ensuring that the implemented solutions remain relevant and effective over time.

4. Case Studies

Empirical evidence from real-world implementations offers valuable insights into the practicalities of applying smartness and sustainability frameworks [10], [14], [17]. These case studies illuminate the tangible impacts, encountered obstacles, and strategic successes of urban smartness initiatives, serving as a repository of lessons learned and best practices. They underscore the importance of empirical validation in refining proposed frameworks and adapting strategies to local needs and opportunities.

The case studies also highlight the role of pilot projects in demonstrating the feasibility and scalability of smart technologies. Successful pilot projects can serve as models for broader implementation, showcasing the potential benefits and providing a roadmap for other cities to follow. Furthermore, these case studies reveal the critical role of community engagement in ensuring the acceptance and success of smart city initiatives. By actively involving residents in the planning and implementation processes, cities can foster a sense of ownership and cooperation, leading to more sustainable and resilient urban environments.

Table 1 is an analytic table that encompasses the thematic findings related to the overarching themes identified above.

TABLE I. ANALYTIC TABLE OF REVIEWED PAPERS

Ref	Theme	Key Contributions
[1]	Proposed Frameworks	Examines digital innovation for enhancing neighborhood smartness, emphasizing technology integration.
[2]	Proposed Frameworks	Proposes a novel framework for neighborhood smartness measurement, focusing on sustainability and stakeholder engagement.
[3]	Challenges in Upscaling	Reviews sustainability assessment tools, highlighting the gap in neighborhood-level assessments.
[4]	Challenges in Upscaling	Discusses methodological limitations in current sustainability assessment tools for neighborhoods.
[5]	Indicators of Smartness	Analyzes urban sustainability indicators, providing insights into current practices and gaps.
[6]	Proposed Frameworks	Offers a replicable and KPI-driven framework aimed at enhancing city smartness and sustainability.
[7]	Proposed Frameworks	Reviews smart solutions in urban development projects across Europe, focusing on the construction sector.
[8]	Indicators of Smartness	Evaluates urban sustainability, underscoring the importance of comprehensive assessments.
[9]	Indicators of Smartness	Details a discrete choice experiment for weighting KPIs in smart local energy systems.

Ref	Theme	Key Contributions
[10]	Case Studies	Reviews worldwide neighborhood sustainability assessments, emphasizing the need for adaptable tools.
[11]	Proposed Frameworks	Proposes a framework for classifying smart city performance indicators, based on data objectivity and technology level.
[12]	Indicators of Smartness	Introduces KPIs for evaluating energy communities, focusing on sustainable technologies.
[13]	Proposed Frameworks	Proposes CAMSUD, a multi-criteria system for sustainable urban development planning.
[14]	Case Studies	Advances neighborhood sustainability assessment by integrating Sustainable Development Goals.
[15]	Challenges in Upscaling	Develops a sustainability framework for small-sized urban neighborhoods using fuzzy evaluation.
[16]	Proposed Frameworks	Offers a comparative analysis of NSA tools, developing integrated criteria for urban development.
[17]	Case Studies	Evaluates citizen-led urban greening projects, highlighting community engagement and smart tech usage.
[18]	Proposed Frameworks	Discusses a KPI-driven framework for sustainable and smart cities, emphasizing multi-pillar integration.

III. FINDINGS CATALOGUE

The thematic analysis culminated in the creation of a detailed catalogue that systematically organizes the literature according to the identified themes. Each entry in the catalogue specifies the study's objectives, methodologies, principal findings, and any proposed frameworks or models, offering a comprehensive overview of the state of research in urban smartness and sustainability. This organized synthesis not only facilitates an in-depth understanding of each theme but also underscores the interconnectedness of the challenges and solutions proposed in the literature. The findings catalogue of the reviewed papers is included in Table 2.

The thematic analysis reveals a consensus on the need for a multidisciplinary approach to smart urban development, integrating technological, environmental, and social considerations. It also highlights the dynamic evolution of smartness indicators, the importance of overcoming scalability challenges, the innovative potential of proposed frameworks, and the instructive value of case studies in navigating the complexities of sustainable urban development.

One of the key insights from the findings catalogue is the recognition that urban smartness is inherently multifaceted, requiring the convergence of various disciplines such as urban planning, engineering, computer science, and social sciences. This interdisciplinary approach ensures that smart city initiatives are not only technologically advanced but also socially inclusive and environmentally sustainable. The reviewed literature emphasizes that successful smart urban development must balance technological innovation with the needs and well-being of the community, fostering environments that are both intelligent and livable.

Another critical finding is the importance of adaptive and scalable frameworks that can be tailored to the unique characteristics of different urban environments. The catalogue highlights several innovative frameworks that address the challenges of scalability by incorporating

TABLE II. FINDINGS CATALOGUE OF REVIEWED PAPERS

Theme	Ref	Study Objectives	Methodology
Proposed Frameworks	[1], [2], [6], [7], [11], [13], [16], [18]	Develop comprehensive frameworks for enhancing urban smartness and sustainability.	Reviews of innovations and smart solutions; development of classification and multi-criteria systems.
Challenges in Upscaling	[3], [4], [15]	Evaluate and address scalability challenges of sustainability assessment tools for neighborhoods.	Critical reviews, analysis of methodological limitations, development of a fuzzy evaluation framework.
Indicators of Smartness	[5], [8], [9], [12]	Analyze and improve urban sustainability indicators and KPIs.	Systematic analysis, evaluation of assessments, discrete choice experiments for KPI weighting.
Case Studies	[10], [14], [17]	Review and evaluate sustainability assessments and urban greening projects in various contexts.	Analysis of worldwide case studies, integration of SDGs, evaluation of citizen-led projects.
Theme	Ref	Principal Findings	Proposed Frameworks/Models
Proposed Frameworks	[1], [2], [6], [7], [11], [13], [16], [18]	Identified integrative, stakeholder-engaged, KPI-driven approaches for smart urban development.	Various frameworks aimed at digital innovation integration, smartness measurement, smart city indicator classification, comprehensive urban planning.
Challenges in Upscaling	[3], [4], [15]	Highlighted gaps and challenges in assessment tools, emphasizing adaptable tools for small neighborhoods.	Guidelines for enhancing neighborhood-level assessments; Fuzzy Synthetic Evaluation Framework.
Indicators of Smartness	[5], [8], [9], [12]	Insights into comprehensive sustainability indicators' development and application; importance of KPIs for energy communities.	Comprehensive Urban Sustainability Indicators Framework; Sustainable Technology KPI Framework for Energy Communities.
Case Studies	[10], [14], [17]	Emphasized adaptability of tools and community engagement in sustainability projects.	Global Case Study Synthesis on Neighborhood Sustainability; Citizen-Led Urban Greening Project Framework.

flexibility and adaptability into their design. These frameworks are equipped to handle the diverse technological infrastructures and varied socio-economic contexts found within urban neighborhoods. By ensuring that smart city solutions can be customized to local conditions, these frameworks enhance the feasibility and effectiveness of sustainability initiatives on a broader scale.

The findings also underscore the evolving nature of smartness indicators and their critical role in assessing and guiding smart city projects. The reviewed literature points to the need for continuous refinement of these indicators to keep pace with technological advancements and changing urban dynamics. Effective indicators must capture a wide range of factors, from energy efficiency and environmental impact to social inclusion and community engagement. The development of such comprehensive indicators is essential for providing accurate and actionable insights that drive sustainable urban development.

Lastly, the catalogue highlights the value of empirical validation through case studies, which provide real-world evidence of the practical application and impact of smart city frameworks. These case studies offer invaluable lessons on the successes and challenges encountered in various contexts, helping to refine theoretical models and adapt strategies to local needs. They demonstrate the importance of pilot projects and incremental implementation, allowing cities to test and fine-tune smart solutions before broader deployment. By learning from these real-world examples, urban planners and policymakers can better navigate the complexities of sustainable urban development and create smarter, more resilient cities.

In summary, the findings catalogue offers a comprehensive synthesis of the current state of research in urban smartness and sustainability. It highlights the necessity of a multidisciplinary approach, the importance of adaptive and scalable frameworks, the evolving nature of smartness

indicators, and the instructive value of empirical validation through case studies. These insights provide a solid foundation for future research and practice, guiding the development of smart urban environments that are sustainable, resilient, and inclusive.

IV. CONCLUSIONS

In conclusion, this research marks a significant milestone in the journey towards sustainable, resilient, and intelligent urban environments. It aims to broaden the scope of smartness assessments from individual buildings to the comprehensive scale of neighborhoods. By doing so, it not only fills a critical gap in sustainability evaluation practices but also sets a visionary pathway for the development of sustainable, resilient, and intelligent urban environments. The study's contributions reflect innovative approaches to integrating smart technologies and sustainability practices across broader urban areas.

The systematic literature review conducted in this study has provided quantitative insights into the current state of research in urban smartness and sustainability. Specifically, 44% of the reviewed frameworks emphasize technological integration and stakeholder engagement, highlighting the critical role of these factors in achieving smart urban development. Furthermore, 17% of the literature addresses the complexity of urban infrastructure interdependencies, underscoring the challenges of scalability and the need for flexible, adaptive assessment tools. These findings demonstrate the multifaceted nature of urban smartness and the necessity of interdisciplinary approaches to address its complexities.

Furthermore, future research should address the socio-economic disparities in the adoption and benefits of smart technologies. Ensuring equitable access to smart city solutions and fostering inclusive urban development will be critical for achieving the broader sustainability goals. This involves developing strategies to engage marginalized communities, address digital divides, and promote social cohesion within smart urban environments.

Through methodological rigor and a systematic literature review, this study has distilled valuable insights into the integration of smart technologies in urban planning. It lays out a strategic pathway that not only navigates the challenges of urban sustainability but also fosters environments where technology and community well-being intersect harmoniously.

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