Sustainable Futures 10 (2025) 101173

Contents lists available at ScienceDirect

Sustainable Futures

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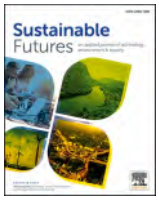

Neighborhood sustainability assessment tools: A systematic review and typology of research

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ARTICLE INFO

Keywords:
Sustainable urban design frameworks
Neighborhood Sustainability Assessment Tools (NSATs)
Sustainability
Research typology

ABSTRACT

Almost two decades after the first neighborhood sustainability assessment tool (NSAT) appeared, research on these tools has grown rapidly and covers diverse perspectives. A critical view of this research helps improve the development and application of NSATs. This systematic review classifies 207 studies by their objectives and identifies key methodological gaps. Using the PRISMA checklist, we selected and analyzed relevant publications in two screening stages. Inductive qualitative content analysis revealed eight main research types. We used a multiple-researcher approach to ensure unbiased classification (Cohen's kappa = 0.87). For each research type, we highlight specific methodological shortcomings and suggest improvements. Some of these include integrating both qualitative and quantitative methods, adopting methods capable of considering the linkages between indicators when developing a new NSAT, and conducting more longitudinal research when evaluating certified developments or assessing the factors affecting the adoption of the tools. We recommend future studies for evaluating the suitability of known universal NSATs for use in developing countries; developing NSATs for countries with high pollution and emission levels, and so on. The study is grounded in three urban sustainability theories-Transition Theory, Adaptive Governance, and Socio-Technical Regimes-which support the typology and analysis. These frameworks clarify how NSATs contribute to urban sustainability transitions, adaptive practices, and socio-technical change.

1. Introduction

Since the mid-1980s, efforts have been made to define the role of urban design in the sustainability of cities [1]. About ten years later, Vale and Vale (1996) believed that the search for an appropriate approach to sustainable environments had not yet been articulated on the basis of a body of documented research that accurately defined the existing problem and explained how urban design could address the goals of urban sustainability [2]. However, urban designers' efforts to address the challenge of urban sustainability have become deeply intertwined with the tradition of impact assessment [3] —a practice that emerged in response to environmental concerns associated with modern development. Impact assessment refers to the process of analyzing and identifying the future consequences and impacts of an ongoing or proposed action. It has become increasingly recognized that engaging with the concept of urban sustainability in all its complexity requires more comprehensive, integrated, and pluralistic perspectives—ones that traditional impact assessment methods such as Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) could not fully accommodate [4,5]. Under the influence of European and North American initiatives, Sustainability Assessment (SA) evolved as the third generation of evaluative frameworks, succeeding EIA and SEA [6]. This shift in approaches and instruments has been crucial in incorporating broader dimensions and criteria of sustainability, enabling the analysis of systemic interactions and dynamics, acknowledging the critical and undeniable role of cities and neighborhoods in global sustainability, and fostering a more contextualized, in-depth, and systematic approach to decision/policy making. This shift, has led to the recent development of multiple international and national sustainability assessment tools at various scales, ranging from individual buildings to entire cities and neighborhoods. Originally designed to tackle the energy crises of the 1980s and 1990s at the building scale, these tools are now applied at urban scales in response to the climate crisis and global agreements like the Kyoto Protocol (1997). Since then, sustainability concerns have shifted from mere energy crises to broader challenges—most notably global warming, greenhouse gas emissions, and growing energy demands [7]. In addition to the world's emerging climate crisis, the contextual issues and challenges of sustainability in

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https://doi.org/10.1016/j.sftr.2025.101173
Received 27 December 2024; Received in revised form 1 August 2025; Accepted 14 August 2025
Available online 22 August 2025

different countries remained in place, and urban design frameworks address such issues. The New Urbanism and the smart growth movement as an example, put their focus on the issue of sprawl growth model of American cities. Thus, the theoretical basis of sustainability assessment tools is "sustainable urban design frameworks" and the required motivations for the development of such tools are the energy crisis and then the climate crisis in addition to the contextual issues of each country. Though if we use a metaphorical language, we can say that the young plant of NSATs and its practical recommendations are rooted in the theoretical foundations of sustainable urban design frameworks (see Fig. 1). For instance, LEED-ND focuses on reducing urban sprawl, increasing transportation choice and decreasing automobile dependence, and other principles followed by smart growth movement and New urbanism [8,9].

Shifting the scale of sustainability assessment tools from buildings to neighborhoods and cities, as mentioned earlier, was a necessity because the intertwined relationship of urban components; and a city cannot be considered sustainable even if all of its buildings become green and zero energy [10,11]. Oktay [12] emphasizes that while zero-energy buildings are an important step towards sustainable cities, they are not sufficient on their own and a holistic approach to sustainability is needed, taking into account the social, economic, and environmental aspects of urban development. Such an attitude provides a rational basis for the efforts made towards the development of NSATs. But do existing NSATs take into account all aspects of urban development and the intertwined relationships between urban components? It seems that the hierarchical system of sustainability indices and indicators used by NSATs to assess the sustainability of urban components, hinders the consideration of interlinkages between indicators [10,13].

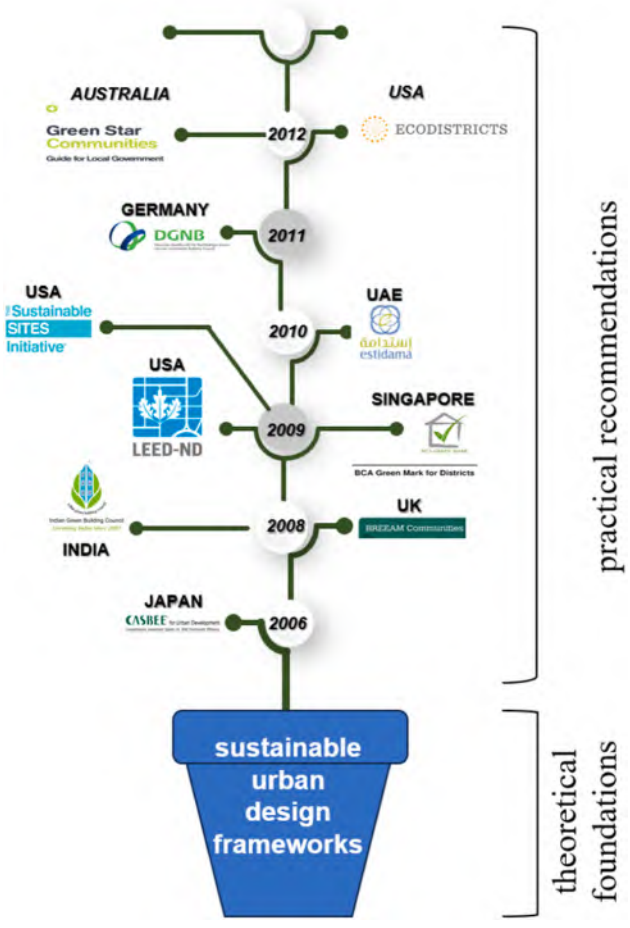

Fig. 1. NSATs are rooted in sustainable urban design frameworks.

Despite the criticism that NSATs face, the need to develop such tools is essential, and efforts to develop new NSATs or improve existing ones are ongoing [14,15].

While a substantial body of research has been conducted on sustainability assessment, most studies have primarily focused on individual tools and their applications [16–18]. However, a significant gap remains in the global literature regarding a comprehensive typology and classification of these tools, a systematic mapping of the full scope and diversity of NSAT research, and clear implications for future sustainability assessment studies. Based on this gap, this study aims to answer following research questions in the body of literature:

RQ1: What is the main purpose of existing studies on neighborhood sustainability assessment tools? (In order to conduct a thematic typology of studies)
RQ2: What are the methodological limitations of the published research under these research types?
RQ3: What are the issues that are left behind or less covered in each type of research? (suggestions for future research to address theoretical and empirical gaps)

This study employed a systematic approach to compile a comprehensive list of publications on NSA tools. Accordingly, all relevant studies from 2007 to the present were identified, and an evaluation sheet was used to examine and extract data from the selected literature. The subsequent sections of this paper first outline the search strategy and methodological approach employed to identify the relevant literature. This is followed by the development of a typology based on the research objectives of the selected studies. Each research type is then examined in detail, with the second and third research questions (RQs) addressed within the respective sections.

To strengthen the theoretical foundation of the proposed typology, we draw on three complementary paradigms: Transition Theory, Adaptive Governance, and Socio-Technical Regimes. Transition Theory's Multi-Level Perspective (MLP) conceptualizes sustainability transitions as dynamic interactions among niche innovations (e.g., novel sustainability assessment tools), socio-technical regimes (e.g., dominant urban planning practices), and landscape pressures (e.g., global climate policies or SDGs). It emphasizes processes like multidimensional learning, network formation, and expectation articulation to drive systemic change in urban systems [19–21]. Adaptive Governance frames urban systems as complex adaptive systems, advocating polycentric, reflexive governance structures that foster resilience through iterative stakeholder collaboration and self-organization, enabling adaptive responses to socio-ecological uncertainties like climate vulnerabilities [22,23]. Socio-Technical Regimes theory defines regimes as interlocked technological, institutional, and cultural configurations, creating path dependencies (e.g., fossil fuel-based infrastructures). It highlights mechanisms like knowledge co-production to overcome institutional lock-ins and reconfigure urban systems [24,25]. The linkage between these paradigms and the typology's eight research types (RTs) is explored in the discussion and conclusion.

2. Research method

This paper employed the PRISMA checklist to guide the systematic review process. PRISMA is an evidence-based minimum set of items for reporting in systematic reviews which helps researchers to improve the reporting of systematic reviews [26]. Fig. 2 illustrates the steps we followed in this study:

The first string was developed to target common terms related to NSATs, such as "Neighborhood Sustainability Assessment Tool" and commonly known tools (e.g. "LEED-ND"). The Scopus database was utilized to conduct the initial search, yielding a total of 363 documents as of March 14, 2023 (the initial search string is provided in Appendix A).

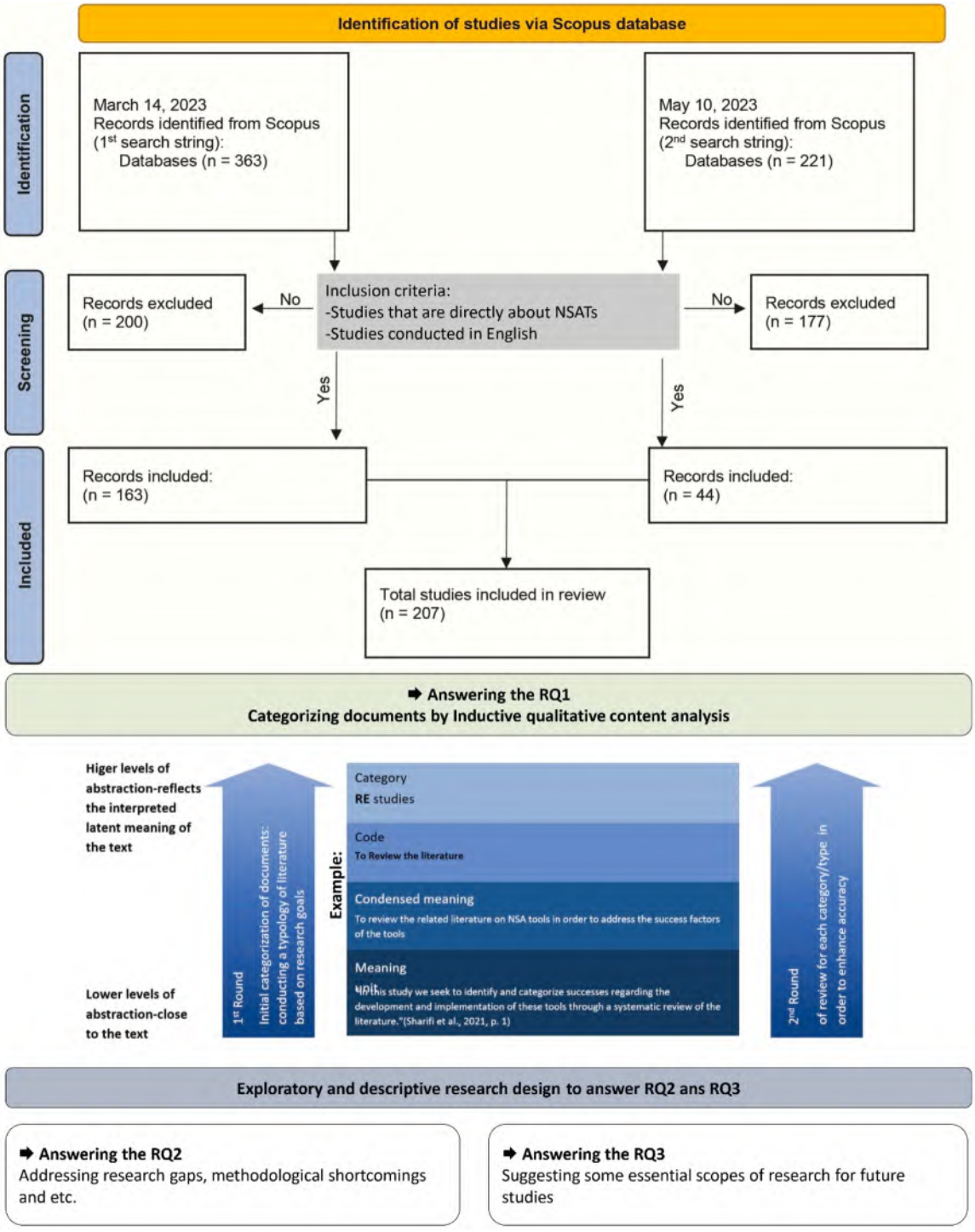

Fig. 2. Literature selection, data extraction and reporting results procedures; Appendices A & B show the search strings.

In the first screening stage, we reviewed abstracts to remove duplicates and exclude irrelevant studies.To ensure a comprehensive set of documents for analysis, a second search string was defined. Building on insights from the initial screening, we refined our second search string to include less-common NSAT names (e.g., "HQE2R") that the first string had overlooked. This phase of search was also based on the topic of documents (i.e. title, abstract and key words). Appendix B shows our second search string. The result was a total of 221 documents in May 10, 2023. after performing the second step of screening a complete list of 207 related documents were chosen for review and analysis. The inclusion and exclusion criteria for the literature to be selected were simple; studies that were directly about NSATs were selected. since the name of some NSATs we used in our search string were common words in English (e.g., Envision) or were the name of private companies that have nothing to do with NSATs (e.g., Envirodevelopment) many other documents were excluded.

We applied inductive qualitative content analysis to 207 articles on NSATs, which yielded eight distinct research types organized by primary objectives.The analysis proceeded in three stages [27–31]. First, the condensation phase, where text segments (meaning units) were shortened while preserving their core meaning; second, the coding phase, where condensed units were labeled with descriptive codes aligned with

the research objectives; and finally, the categorization phase, where codes were grouped into eight distinct categories based on content, context, and shared objectives, ensuring each article was assigned to a single category. In cases where a study appeared to touch on multiple themes, we referred back to the coding phase to identify its dominant focus. Classification was then made based on the most prominent research objective, taking into account both the frequency of relevant codes and the broader context in which the study framed its contribution. Thematic analysis, which involves extracting latent content and underlying meanings, was beyond the scope of this study. To ensure the validity of the qualitative analysis, a multi-researcher approach was adopted [32]. Two independent researchers conducted the analysis separately and reached a consensus on coding and data classification through weekly meetings. Inter-coder agreement was assessed using Cohen's kappa coefficient ($\kappa = 0.87$), indicating a high level of agreement and analytical reliability. Finally, to address RQ2 and RQ3, we employed an exploratory, descriptive approach.

3. Results

As previously stated, 207 documents were selected for review and analysis. An examination of the geographical distribution of publications since 2007 reveals an increase in publications from developing countries (i.e., Asian, African, Middle Eastern, and South American countries). This is a promising trend, indicating that such countries are Increasingly acknowledging the importance of urban areas in sustainability (Fig. 3).

3.1. Categorization of publications: 8 research types (RTs)

As previously mentioned, following the second review, eight research types (RTs) were identified to categorize the selected literature (Table 1).

The following sections provide a detailed review of these eight research types, along with corresponding examples.

3.1.1. RT 1 (AE): application of NSATs to measure the sustainability of existing developments, planning approaches or proposed neighborhood layouts

The first category of studies is aimed to apply NSATs in order to assess the sustainability of existing developments [33–36], planning approaches [37,38] or proposed neighborhood layouts [39]. The dominant approach of these studies is almost affirmative; in the sense that they consider the existing NSATs and their criteria and indicators to be sufficient and valid for assessing sustainability, these studies almost do not criticize the adequacy of such tools.

LEED-ND is employed with greater frequency by researchers engaged in such studies than other NSATs. In recent years, a growing number of studies have emerged from researchers in Arab countries in the Middle East expressing a desire to revise and enhance green policies and to present their newly developed NSATs (in this case, Estidama) to the academic community [40,41].

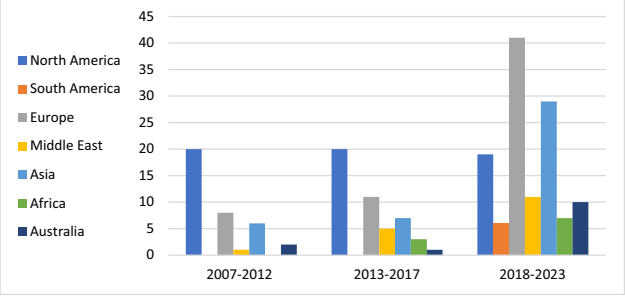

Fig. 3. The geographical and temporal distribution of reviewed documents.

Table 1
Research types (RTs) and allocated codes to each RT in this paper.

Research Types (RTs)		
1	AE	**A**pplication of **E**xisting NSATs to measure the sustainability of Existing developments, Planning approaches or proposed neighborhood layouts.
2	DN	To **D**evelop a **N**ew NSAT or enhance existing tools
3	IE	To **I**nvestigate the **E**xisting tools
4	RE	To **R**eview the related literature on **E**xisting NSATs
5	IC	To **I**nvestigate **C**ertified developments
6	FE	To identify **F**actors affecting the adoption of **E**xisting NSATs
7	DE	To **D**esign neighborhoods based on **E**xisting NSATs
8	PE	To **P**resent an **E**xisting NSAT

The assessment of planning approaches or policies, as mentioned before is a sub-category of the AE research type. Some studies focus on urban codes as a means to guide the incremental development of the city. In his studies, Garde focuses on zoning reform in cities. Comparing the traditional zoning system with the new form-based code, he attempts to use the existing NSATs as a metric to evaluate the sustainability function of such codes [37,42,43]. Garde et al. [37] suggest that planners in municipalities seeking alternatives to their traditional zoning code not only consider replacing it with an FBC, but also incorporate LEED-ND planning principles to strengthen the proposed code. Talen et al. [44], use LEED-ND's "Smart Location and Linkage" to prioritize development areas in Phoenix. They suggest that in these designated areas, developers could be offered incentives such as bonus zoning, property tax rebates, and fee waivers. These studies suggest that NSATs may serve as valuable tools for policymakers and urban planners to guide sustainable change management at the city level. In a similar research, Pedro et al. [14] argue that the non-spatial nature of existing NSATs has prevented them from functioning as a supporter of urban planning policies. Therefore, in the Lisbon case study, they integrate GIS with BREEAM-Co to identify priority intervention areas for sustainable development.

3.1.1.1. Methodological considerations for AE studies. About half of the AE studies used quantitative methods [34,38,41,45]; Although this enhances clarity and reliability, it also signals a lack of critical engagement with the tools' limitations. Today, having identified the shortcomings of international NSATs [46], they cannot be considered as an absolute criterion for measuring the sustainability of policies and projects. Some studies, applied NSATs developed for western settings, without rethinking their fit for places like Saudi Arabia or Brazil [36,47]. This can miss local nuances- cultural values or environmental realities. On the other hand, some studies lean too heavily on qualitative approaches, ignoring the quantitatively measurable data like energy use or emissions [48]. Studies must acknowledge the limitations of NSATs. A realistic approach would be to benchmark the international NSATs against local standards before applying them.

3.1.1.2. Suggestions for future AE researches. As mentioned earlier, leading and international NSATs' assessment priorities may not reflect the local priorities of developing or less-developed countries; the availability of required data for assessment according to the international NSATs in these countries must also be considered [49]. It seems that any effort to apply NSATs in local contexts must be accompanied by an in-depth qualitative assessment method (e.g., community surveys) to compensate for the limitations of NSAT assessment results.

Another point to consider is the static and cross-sectional nature of AE studies. Such an approach does not capture how cities change over time. An alternative approach is a long-term assessment that allows policymakers to monitor the sustainability of developments over time. Such an approach also help the NSAT developers to rethink the tool priorities over time and according to emerging challenges (i.e. climate change) [50].

The primary planning policies and approaches assessed through the

use of NSATs include urban codes and land readjustment [45], social housing [51], and brown field renovation [52]. However, the majority of planning approaches and policies have been overlooked by researchers. Urban regeneration, particularly in historic cities, serves as a case in point.

3.1.2. RT 2 (DN): to develop a new NSAT or enhance existing tools

DN research type includes any attempt to develop a new NSAT, or to upgrade existing ones. Some DN studies endeavor to develop tools for particular sites. For example, Kaur and Garg [53] conducted research to create a tool for hillside sites, while P.de Alencar et al. [54] sought to develop a tool for coastal zones. Zargarian et al. [55] examined the sustainability assessment of urban underground spaces. Similarly, Thompson et al. [56] conducted research to develop a tool for ferry terminals, while Crosson [57] created a tool to assess the sustainability of transit centers. Such tools are henceforth referred to as "site-specific" tools. Other studies are attempting to concentrate on a particular subject within the framework of the NSATs. Inclusiveness [58,59], public participation [60], and environmental equity [61] are among the key areas of focus. The studies also address quality of life [62], and the resiliency of infrastructures [63], with the objective of developing a "topic-based" NSAT.

The deficiencies in the current NSATs in terms of providing equal coverage of the various dimensions of sustainability have prompted researchers to develop solutions to this shortcoming. The review by Salati et al. [64] of four common NSATs with the objective of establishing a consistent set of sustainability indicators "independent of the local context" represents a significant contribution to the field. Similarly, the efforts by Yakoub et al. [65] to develop an NSAT with “a comprehensive assessment framework” that sufficiently covers environmental indicators, or the study by Gargiulo et al. [66] with the aim of identifying the minimum set of parameters needed to guarantee the sustainability of urban developments, are examples of such research. These studies attempt to create a "holistic" NSAT for global use.

However, due to the limited coverage of sustainability dimensions [46], NSATs are subject to a more rigorous critique: the use of a "one--size-fits-all" approach. Consequently, a third category of DN research aims to develop tools that address contextual issues. These tools are designated as "area-specific" NSATs, as they address the issues that are more critical to the sustainability of urban developments in specific contexts and locations (Fig. 4 illustrates the relationship between four types of NSATs). This issue refers to "fitness" as an intellectual tradition in the theory of sustainability. Fitness has its roots in biology and Darwin’s treatise, “On the Origin of Species”. Fitness involves adaptability and appropriateness over time, that is, compatibility between the organism and the habitat [67]. The old metaphor of the city as a “living organism” [68] is still valid [69]. Each city faces unique ecological, societal, and economic challenges, requiring customized approaches to sustainability. Factors such as climate, population density, infrastructure, and cultural norms can all influence the specific sustainability issues a city or neighborhood must tackle. Therefore, it is not possible to assess the sustainability of the neighborhoods using general and standard criteria and indicators for urban areas around the world. Table 2 shows area-specific NSATs developed to address specific issues of each context.

Addressing the contextual issues in such studies also embeds a procedural critique of the expert-initiated production process of existing NSATs [70]. The prevailing critique is that the existing NSATs are tailored to the circumstances in the countries of origin—that is, developed countries—and thus fail to address the priority issues of developing countries. As Fig. 5 shows, in order to overcome this shortcoming, emerging NSATs need to compile a set of related criteria and indicators (Step 1) and assign weights to them in accordance with the contextual priorities (Step 2). Integrating a bottom-up approach with a top-down approach in the selection of relevant criteria and indicators (Step 1) would assist NSATs developers in balancing the expert-driven nature of existing tools [49,71] and also in paying more attention to contextual concerns as perceived by stakeholders. Ameen [72] has integrated the opinions of stakeholders with the concerns of experts in order to develop an NSAT for the context of Iraqi cities. The tool underscores the significance of indicators such as "water," "security," and "transportation and infrastructure" due to the impact of political instability and the deterioration of infrastructure over the past 40 years. These issues are considered to be of paramount importance in the Iraqi context. However, existing NSATs, such as LEED-ND, do not accord these indicators the same level of priority.

The last subset of DN research, as mentioned above, are studies that aim to improve an existing NSAT and adapt it to a specific context. For example, Fadli et al. [73] use environmental impact assessment (EIA) framework to enhance the GSAS tool. In the studies by Phondani et al (2016), with the aim of making the GSAS tool more comprehensive while improving ecosystem services, they add indicators related to native plant species to the tool [74,75]. Leafer [76], attempts to quantify the qualitative assessment tool (SPeAR). Thus, she proposes a six-point set of quantitative inputs to better enable the use of a qualitative model for assessment. Yin et al. [77] contend that two of the LEED-ND credits (2 and 9 NPD credits) are not reflective of the realities of Chinese cities. To enhance the adaptability of LEED-ND in China, they propose modifications to the credits and prerequisites of the tool. In their studies, Chiang et al. (2011) have proposed an edited version of SBTOOL that is adapted to the context of Taiwan. In order to address climate change issues, they have increased the weight of related indices that are subsumed into "*Community Symbiosis Environment and Life*" and "*Disaster Prevention and Community Security*" [78,79].

3.1.2.1. Methodological considerations for DN studies. Fig. 5 illustrates the three main stages of the development of an NSAT. However, as shown in Table 2, most studies exhibit limitations at each step, particularly in validating the proposed credit system (Step 3). Authors must use established methods for each step and justify why they chose to use

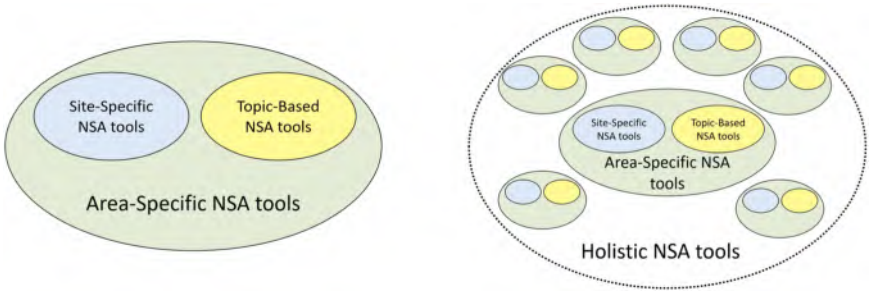

Fig. 4. Left: Taking a contextual approach, area-specific tools address both specific sites and specific issues related to the sustainability challenges of different sites. Right: Holistic tools are characterized by a comprehensive approach, employing a set of criteria that is universally applicable, regardless of context-specific considerations.

Table 2
Area-specific NSATs, their contexts, prioritized issues based on contextual challenges, and methodologies used in key steps of tool development.

Research	1. Context	2.Prioritized sustainability aspects, issues or indices	3.Basic NSATs	Method for selecting the most relevant indicators (Stage1)	Method for criteria weighting (Stage2)	Validation method (Stage 3)
Michell, Moghayedi [85]	South Africa	Energy use efficiency, Water recycling, Pollution control/ light, sound, electrosmog, and hazardous substances, Distance to the workplace	Circles of Sustainability, ISO37120, GBCSA-Sustainable Precinct, HQE2R, CASBEE UD, LEED-ND, BREEAM Co	the panel of experts	Not mentioned	Not mentioned
Momoh, Kangwa [71]	Nigeria	Economic sustainability then other aspects of sustainability which includes social/cultural, planning and environmental will follow.	BREEAM Co, LEED-ND, SuBETooL, Green Star, Green Economy Indicators, CASBEE-UD	questionnaire	questionnaire	Delphi
Cheshmehzangi, Dawodu [89]	China	Not mentioned	CASBEE-UD, GBI Township, Green Mark for Districts, Indian Green Building Council (IGBC) Green Township, BERDE, GSAS, BEAM Plus, The Pearl Community	Multiple analysis of existing tools from different aspects: dimensions, type of indicators, commonalities and context	Not mentioned	Not mentioned
Ali-Toudert and Ji [90] & Ali-Toudert, Ji [13]	Germany	German legislation and standards and implementation mechanisms, i.e. Germany's planning instruments, while at the same time giving equal consideration to sustainability dimensions.	CASBEE-UD, LEED-ND, BREEAM Communities, DGNB-NSQ and Green Star Communities	Multiple analysis of existing tools from different aspects:	Not mentioned	the comparative analysis of a database consisting of 160 sustainable urban projects
Dawodu, Cheshmehzangi [91] & Dawodu, Cheshmehzangi [70]	Nigeria	Economic, social and institutional dimensions of sustainability then environmental dimension.	BREEAM Co, LEED-ND, Green Mark for Districts, Green Building Index, Global Sustainability Assessment System: District, The Pearl Community, Green Star, Green Township, CASBEE-UD	Questionnaire	Not mentioned	Not mentioned
Ameen and Mourshed [92]	Iraq	Water, safety, and transportation and infrastructure indicators	BREEAM Co, LEED-ND, CASBEE-UD, SBToolPT–UP, Pearl Community Rating System (PCRS), GSAS	Delphi	AHP	Not mentioned
Ferwati, Al Saeed [83]	Qatar	Compactness and connectivity	LEED-ND, BREEAM Co, CASBEE-UD, Estidama	The Compression Matrix Development (CMD)	ANP	Implementation of the developed NSAT in Lusail, a city planned and implemented based on QSAS-ND
Mosaad, Darwish [93]	Egypt	An NSA tool to reduce the environmental load of the tourist community	LEED, BREEAM, STAR COMMUNITY, IGBC, PEARL, QSAS	Not mentioned	Not mentioned	Not mentioned
Haider, Hewage [84]	Canada	small-sized neighborhood infrastructure development	BREEAM Co, LEED-ND, CASBEE-UD, Ecocity, earth craft communities (ECC), sustainable community rating (SCR), the Green Proforma	Not mentioned	Fuzzy Synthetic Evaluation (FSE)	Implementation of the developed NSAT in the District of Peachland, British Columbia
Yigitcanlar, Kamruzzaman [49]	Malaysia	environmental, social and then economic indices	Not mentioned	Delphi	Delphi	the sensitivity analysis

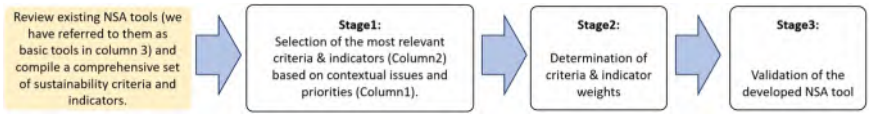

Fig. 5. The main stages in the development of an NSAT tool.

these methods; here are some considerations for each of the aforementioned steps.

First step; selection of the most related criteria and indicators: Yigitcanlar et al. (2016) believe that the process of developing assessment indicators can be expert-led or citizen-led [49]; regardless of the source of extraction of assessment indicators, we consider it necessary to discuss the methods used for this purpose. As the concept of sustainability is inherently contextual, and as such, the selected set of sustainability criteria and indicators, as well as the assigned weights, must reflect the specific issues of the given context, then in-depth qualitative methods (e.g. stakeholder interviews) will help identifying unique urban challenges of each context. However, various reasons, including financial and time constraints, limit participation in compiling the list of indicators and evaluation criteria to experts. In such circumstances, consensus methods must be applied to identify the most related indices. Some of the most commonly employed consensus methods include the Delphi technique, Nominal Group Technique (NGT), and the RAND/UCLA method. The Delphi method has been employed in numerous

studies. The key factors that have made this technique cost-effective and reliable are the use of anonymity [80], and avoidance of face-to-face contact [81].

The second step; assigning weights to the criteria: this step can be addressed by applying multi-criteria decision-making (MCDM) techniques. Examples of such methods include AHP, ANP, FSE, and TOPSIS. Despite the widespread use of AHP in DN research [49,53,72], a main weakness of this method is that it ignores the linkages between indicators. Ali-Toudert et al. [13] posit that mathematical methods (e.g., probability theory, fuzzy logic, etc.) must be employed to account for the interrelationships of criteria at the criteria weighting stage. The analytical network procedure (ANP) is a method that accounts for the relationships between the criteria [82]. Some of the existing NSATs employ this method, including GSAS [83]. Haider, Hewage [84] utilize a more complex method, fuzzy synthetic evaluation (FSE), to address this limitation.

The third step; validation: as mentioned above, is the most common shortcoming of DN research. The absence of pilot testing or case studies [15,64,85], or restricting validation to a single case study [53, 59], raises concerns about the validity of the proposed NSATs. It is crucial to highlight that this phase encompasses a primary validation. Indeed, the validation of an NSAT is a time-consuming process that requires the conduction of empirical studies for the evaluation and monitoring of the function of certified developments in practice [10]. A potential solution to conduct a more reliable primary validation would be to evaluate the same project using both an existing tool and the proposed tool. The resulting differences in outcomes can then be justified on the basis of the contextual factors reflected in the indicators and weights of the proposed tool. The assessment of the layout of a developed urban project and comparison with the status quo sustainability performance of the development in question is an effective approach to validating tools. This method ensures the generation of quantifiable and comparable results.

3.1.2.2. Suggestions for future DN researches. Around 70 % of global CO2 emissions are caused by cities [86] and emissions are increasing due to rapid urbanization in developing countries, so it is essential to focus on urban climate mitigation for effective global mitigation [87]. On the one hand, area-specific NSATs must be developed with a particular focus on the challenges faced by developing or less-developed countries, and on the other hand, countries with the highest pollution rates should give priority to the development of NSATs. It is evident that not all countries are equally responsible for the climate crisis. Therefore, nations with higher pollution and emission levels should prioritize reducing their development impacts.. For example, it is notable that NSATs have not yet been developed in two countries, Russia and Iran, which rank fourth and sixth among the countries with the highest rates of CO2 emissions [88].

3.1.3. RT 3 (IE): to investigate the existing tools

IE studies play a pivotal role in analyzing existing Neighborhood Sustainability Assessment Tools (NSATs), providing insights that inform their improvement and development. These studies serve as a foundation for DN (Development of New NSATs) studies by identifying the strengths and limitations of current tools. Given their interrelationship, IE studies adopt the same classification system as RT2 (DN studies), categorizing investigations as topic-based, site-specific, area-specific, or holistic.

Topic-based IE studies assess whether NSATs address specific themes. For instance, Naji and Gwilliam [94] evaluate BREEAM-Co's potential to support climate change adaptation through governance frameworks, concluding that it effectively promotes community-level adaptation strategies. Sharifi et al. [11] examine the alignment between sustainability and smartness assessment tools, finding limited overlap but noting that NSATs adequately address environmental and mobility indicators. Szibbo [95] analyzes LEED-ND from a social perspective, suggesting it has been less effective in promoting affordable housing to enhance social equity.

Site-specific IE studies focus on the suitability of NSATs for addressing the unique challenges posed by specific sites.. For instance, Kaur and Garg [96] assess the applicability of LEED-ND, BREEAM-Co, and GBI Township in hilly areas, identifying certain indicators as irrelevant for such sites. Their findings inspired a follow-up DN study [53] to develop a site-specific tool, highlighting the connection between IE and DN research.

Area-specific IE studies explore the adaptability of global NSATs to different regional contexts. Argüello Meza et al. [97] investigate the suitability of global NSATs for Paraguay, emphasizing that developing countries prioritize issues like wastewater management and public transportation. Similarly, Kyrkou and Karthaus [98] stress the importance of assessing local conditions to adapt universal NSATs like BREEAM and LEED-ND for specific regions.

Holistic IE studies evaluate the comprehensiveness of NSAT criteria against theoretical sustainability frameworks, such as Barbier's three pillars [99], Elkington's triple bottom line [100], or Spangenberg and Bonniot's four-dimensional Prism of Sustainable Development [101], as well as the United Nations' 17 Sustainable Development Goals (SDGs).

Saiu and Meloni [102] compare LEED-ND, BREEAM-Co, and ITACA, finding that these tools prioritize urban issues (SDG 11), climate action (SDG 13), and responsible production (SDGs 9 and 12), but give less attention to social wellbeing (SDGs 3, 8, 9). Diaz-Sarachaga et al. [103] use the SDGs to assess LEED-ND and Envision in less-developed countries, noting that Envision incorporates more SDGs (11) than LEED-ND (8) but both undervalue economic and social goals.

Purvis, Mao [104] argue that while contemporary sustainability literature predominantly focuses on the UN's more diverse set of SDGs, the older frameworks, such as the three pillars, were explicitly embedded in the formulation of the SDGs. Many authors have evaluated how NSATs address various sustainability dimensions in light of this understanding.Berardi [105] and Wu et al. [106] further highlight that NSATs like BREEAM-Co, LEED-ND, and CASBEE-UD often prioritize environmental over social and economic dimensions, limiting their holistic applicability..

3.1.3.1. Methodological considerations for IE studies. This study focuses on the methodological aspects of area-specific IE investigations, which assess the adaptability of NSATs to diverse regional contexts. Comparative content analysis of NSAT frameworks or policy documents, as conducted by Diaz-Sarachaga et al. [103,107]. highlights differences between the sustainability priorities of global NSATs and those of developing countries. However, achieving a nuanced understanding of contextual issues requires qualitative methods, such as in-depth stakeholder interviews or focus groups. For example, Meza et al. (2021) used semi-structured interviews with local experts in Asunción, Paraguay, to identify distinct sustainability priorities, such as wastewater management, that differ from those of developed countries. While their approach is robust, further clarification on methodological choices, such as sample size justification (e.g., achieving theoretical saturation with 33 interviews), could strengthen the findings. Qualitative methods should complement content analysis to capture local nuances effectively, ensuring that NSAT assessments reflect regional priorities [97].

3.1.3.2. Suggestions for future IE researches. Our focus on area-specific investigations is driven by the need to highlight the contextual nature Area-specific IE studies are critical for addressing the contextual nature of sustainability, particularly in developing countries where rapid urbanization amplifies environmental challenges, such as CO2 emissions [108,109]. These studies can highlight the applicability of holistic NSATs in such contexts, encouraging the development of tools tailored to local needs. Future IE studies should prioritize evaluating how global

NSATs address region-specific challenges, such as infrastructure limitations or socio-economic disparities, to support the creation of context-sensitive tools.

Additionally, IE studies would benefit from examining different versions of established NSATs to assess improvements over time, as suggested by Sharifi et al. [46]. Tracking the evolution of tools like LEED-ND or BREEAM-Co could provide insights into their adaptability and effectiveness, ensuring that NSATs remain relevant to diverse urban challenges.

3.1.4. RT 4 (RE): to review the related literature on NSATs

RE studies serve as a baseline for researchers interested in comprehending the status quo and future of research on NSATs. Thus, we meticulously analyze the significant RE publications to paint a detailed picture.

Sharifi and colleagues, key contributors to neighborhood sustainability assessment research, have authored three of the seven RE studies reviewed in this paper. In two of these works [46,110], a systematic review of 117 publications was conducted to classify success factors and identify methodological limitations of Neighborhood Sustainability Assessment Tools (NSATs). A summary of this review is provided below. As indicated in Table 3, six of the eight limitations identified in the second paper were reframed as potential success factors for NSATs in the first paper. The authors offer "recommendations to address limitations" in their conclusions; however, these recommendations often lack specific, actionable steps for improving tools. For instance, the suggestion to enhance the "inclusion of social, economic, and institutional indicators" to address the issue of "limited coverage of sustainability dimensions" may not provide sufficient guidance for tool developers seeking to address these shortcomings [46].

Table 3
Limitations and success factors of NSATs by [46,110]. Items that are opposite each other are written in the same row of the table.

Limitations in assessment methodologies	success factors	
	Tool improvement over time	Structural success
Lack of measures to ensure that basic sustainability requirements are met	Providing measurable indicators for assessment	
Limited consideration of context-specific issues	Local tools ensure context specificity	
Limited coverage of sustainability dimensions	Adequate coverage of sustainability dimensions	
	Design standards of NSATs can provide co-benefits (e.g., public health)	
	Upscaling building-based activities	
Limited accounting off or interlinkages between indicators	Providing methods for dealing with interactions between different indicators	
Complexity of the assessment tool	User friendliness	
	Promoting sustainable design	Procedural success
	Improving performance (walkability, quality of life and resident satisfaction, costs, revitalization, sprawl control)	
	Highlighting priority development locations and areas that need further improvement	
Top-down and non-transparent approaches	Facilitating stakeholder engagement and improving transparency	
	Informing decision making	
	Relative success in terms of adoption	
	Expediting planning and decision-making processes	
Rigidity and prescriptiveness of design measures		
Lack of agreement between different assessment methodologies provided by different tools		

It is critical to acknowledge that methodological limitations observed in a single NSAT should not be generalized to all such tools, as this would constitute a logical error of overgeneralization.

In their initial paper, the authors effectively addressed this concern by clearly delineating the success factors of NSATs and specifying the relevant tools in a separate column of the table, thereby enhancing the precision of their analysis. Consolidating the insights from both papers into a single, cohesive publication could further strengthen the clarity and impact of their findings, helping to address the inconsistencies noted in Table 3 and ensuring a more comprehensive contribution to the field.

Dawodu, Cheshmehzangi [111] discuss how the qualitative nature of the literature on NSATs can limit the precision of research findings. A key strength of their study lies in its critical approach, which contrasts with the more affirmative perspectives often found in the literature. The authors also identify factors contributing to increased NSAT research during specific periods, such as the adoption of the 17 Sustainable Development Goals (SDGs) in 2015. This analysis enhances readers' understanding of how global events shape research priorities and highlights the evolving sustainability needs of communities. The study further notes that the lack of context-specific indicators in tools like LEED-ND and BREEAM-Co has driven the development of area-specific NSATs, as illustrated in Fig. 4. Additionally, the authors observe a notable decline in certified projects in 2020, attributing this to the reallocation of resources toward health-related initiatives during the global pandemic. This insight underscores the need for NSAT developers and researchers to consider incorporating health-related and pandemic resilience indicators, reflecting the study's valuable connection between NSAT evolution and major global events.

In their comprehensive review of NSAT literature in Global South countries, Asaad et al. [112] provide a thematic classification of research studies and present their findings in a clear high- and low-priority matrix to guide future research. They identify studies focusing on specific indicators within neighborhood certification systems or comparing recently developed local NSATs as high-priority research areas. Addressing research gaps and underexplored themes is a central aim of RE studies, and Asaad et al. effectively achieve this objective. However, their review would benefit from further discussion of the methodological challenges identified in the literature, which could enhance the depth and applicability of their findings.

3.1.4.1. Methodological considerations for RE studies. RE studies often adopt an affirmative stance, focusing on summarizing existing literature rather than critically evaluating its methodological rigor. While some studies, such as Sharifi et al. [46], provide valuable critical insights, many RE studies do not sufficiently assess the quality of the reviewed literature, such as the robustness of research designs or the reliability of data sources. This limits the depth of their contributions to advancing NSAT development.

To strengthen their impact, RE researchers should aim to avoid overgeneralizing findings from specific NSATs to all such tools, as this may obscure context-specific nuances and hinder tool developers' ability to address substantive and procedural gaps. A more critical approach, incorporating precise and well-supported critiques of NSATs, could enhance the utility of RE studies for practitioners and researchers alike.

While qualitative studies offer valuable insights into contextual factors, integrating quantitative methods can further strengthen the evaluation of NSAT indicators across various sustainability themes. To this end, RE studies could benefit from prioritizing literature that employs both qualitative and quantitative approaches to assess the strengths and limitations of current NSATs, thereby providing a more

comprehensive foundation for future research and tool development.

3.1.4.2. Suggestions for future RE researches. RE studies can significantly enhance readers' contextual understanding of how global sustainability agendas and evolving urban challenges shape the development of Neighborhood Sustainability Assessment Tools (NSATs). Of the eight RE studies reviewed, only three [7,10,14] explicitly connect international policies, such as the 2015 Sustainable Development Goals, to the evolution of NSAT research priorities. These studies could further strengthen their contribution by more directly linking recent global events, such as climate policy shifts or urbanization trends, to the development of NSATs over time.

This contextual understanding not only highlights potential research gaps but also informs the prioritization of key themes in NSAT studies. By fostering awareness of how global and local factors influence assessment criteria and indicators, RE studies guide researchers in selecting methodologically robust and contextually relevant approaches. This, in turn, enhances the ability of NSATs to address diverse sustainability dimensions, such as environmental, social, and economic aspects. Through such insights, RE studies provide valuable guidance for researchers across the eight research types (RTs) discussed in this article, supporting the practical advancement of sustainability assessment tools.

3.1.5. RT 5 (IC): to investigate certified developments

IC studies play a critical role in evaluating whether certified projects deliver measurable sustainability outcomes or primarily serve as tools to enhance market appeal. These studies provide developers and stakeholders with evidence-based insights into the environmental, social, and economic impacts of implementing Neighborhood Sustainability Assessment Tools (NSATs). Given the high costs associated with certification, such insights can help address developers' concerns about pursuing certification and inform tool developers in refining assessment frameworks to better align with sustainability goals.

Several IC studies have examined LEED-ND pilot projects to assess their outcomes. For instance, Martino, Trigueiro [113], analyze the morphological aspects of two LEED-ND-certified Olympic villages (Southeast False Creek in Vancouver and Ilha Pura Condominium in Rio de Janeiro) to evaluate their impact on urban vitality. Using space syntax techniques, the study highlights how external factors, such as urban policies and connectivity, influence project vitality. Stevens and Brown [114] investigate the effect of community design on moderate-to-vigorous physical activity (MVPA) among 187 fifth graders in three communities. Their analysis of covariance reveals that walkable community designs, aligned with LEED-ND standards, positively influence students' MVPA. Gallimore, Brown [115] employ the Irvine-Minnesota Inventory (IMI) walkability audit tool to compare parents' and children's perceptions of walking barriers in three communities, finding that a LEED-ND pilot community exhibits greater walkability compared to a standard suburban neighborhood. In their study, Smith and Bereitschaft [116] explore the relationship between the Smart Location and Linkage (SLL) credit category—a core component of the LEED-ND framework, given its emphasis on sustainable urban form—and urbanization indicators such as land cover index and nighttime lights. Using GIS analysis, the study demonstrates that the SLL criteria, which are prerequisites for certification, effectively support LEED-ND's objectives of mitigating urban sprawl, particularly in the context of American cities where sprawl remains a significant challenge. These findings underscore the value of IC studies in providing actionable insights for improving NSAT frameworks and ensuring certified projects achieve meaningful sustainability outcomes.

3.1.5.1. Methodological considerations for IC studies. At first glance, the reviewed IC studies demonstrate alignment between their selected methods and research objectives, as summarized in Table 4, which outlines the studies, their aims, and the methods employed. For example, Gallimore, Brown [115] utilized the Irvine-Minnesota Inventory (IMI), a well-established walkability audit tool, to assess the walkability of LEED-ND-certified projects. Similarly, Smith and Bereitschaft [116] employed remote sensing techniques to evaluate the locational attributes of certified projects, while Stevens and Brown [114] used ActiGraph accelerometers to measure students' physical activity levels, supplemented by a qualitative assessment of parental preferences.

Table 4
Methodological aspects of IC researches.

Study	Type of investigation	Aim	Aspect
Martino, Trigueiro [113]	Quantitative	Vitality assessment	Social (vitality of the urban spaces)
Smith and Bereitschaft [116]	Quantitative	Assessment of achievement of LEED-ND goals through the Smart Location and Linkage score	Environmental (Locational attributes)
Stevens and Brown [114]	Quantitative	Walkability assessment	Social (physical activity of the residents)
Gallimore, Brown [115]	Qualitative & Quantitative	Walkability assessment	Social (physical activity of the residents) & Environmental

A closer examination reveals that many IC studies favor quantitative methods, often prioritizing measurable outcomes over perceptual or contextual factors. For instance, structured, close-ended questionnaires, such as the IMI, limit responses to complex issues like parental preferences to simplified scales (e.g., 4-point scales or single-word answers). While quantitative methods offer valuable precision, relying solely on them to assess qualitative aspects, such as walkability perceptions, may oversimplify the analysis. Incorporating qualitative methods, such as in-depth interviews or perceptual surveys, could provide a more comprehensive understanding of these complex issues.

Additionally, IC studies predominantly adopt cross-sectional designs, which capture a snapshot in time but may not reflect changes in project outcomes or resident perceptions over time. Among the reviewed studies, only two employed a longitudinal approach. For instance, Breysse et al. [110] assessed the health impacts of a green-renovated low-income housing project, collecting data at baseline and one year later [117]. A similar study [118] examined health outcomes in a Washington, DC, low-income housing renovation over the same period. While these studies provide valuable insights into short-term impacts, they do not explore whether benefits persist over longer periods, highlighting the need for extended longitudinal research to capture the evolving impacts of certified projects.

3.1.5.2. Suggestions for future IC researches. The tendency of IC studies to rely heavily on quantitative methods for assessing complex issues, such as walkability or environmental qualities, may limit the depth of their findings for urban designers and tool developers. To enhance the applicability of IC research for refining NSAT frameworks, studies could benefit from integrating qualitative methods, such as in-depth interviews and field observations, alongside quantitative approaches. This balanced methodology would provide a more nuanced understanding of resident experiences and contextual factors.

As posited by Sharifi, Dawodu [46], NSATs often evaluate neighborhoods as standalone entities, overlooking their interconnections with the broader urban context. This limitation can create uncertainty about the long-term success of certified projects. For example, Martino, Trigueiro [113] found that external factors, such as Brazil's economic recession, informal community encirclement, and restrictive urban codes, contributed to the social and economic challenges faced by the

Ilha Pura Condominium project. Future IC studies could strengthen their analyses by examining how such external factors influence the socio-economic outcomes of certified projects, ensuring a more holistic assessment of sustainability.

Furthermore, transitioning from cross-sectional to longitudinal assessments would enable researchers to evaluate whether the environmental and social benefits of certified developments persist, adapt, or diminish over time. Longitudinal studies are better suited to capturing the evolving impacts of projects as they face new urban challenges, providing critical insights for tool developers and policymakers aiming to enhance the effectiveness of NSATs.

3.1.6. RT 6 (FE): to identify factors affecting the adoption of NSATs

FE studies play a crucial role in identifying barriers and incentives that influence the adoption of Neighborhood Sustainability Assessment Tools (NSATs), supporting both the financial viability of these tools and the sustainability goals of communities. While NSATs aim to promote sustainable urban development, their adoption is often shaped by economic considerations, making FE studies valuable for tool developers and policymakers. However, FE studies constitute a small proportion of the literature, with only 4 of the 207 publications reviewed here categorized as FE, as shown in Table 5, which lists these studies and the key factors they identified. The following sections explore these studies in detail.

Kochhar, Mahal [119] conducted a detailed analysis of institutional mechanisms for incentivizing GRIHA projects across Indian states (Table 6), proposing recommendations for states and municipal bodies to enhance NSAT adoption.

These include transitioning gradually from incentive-based policies to mandatory regulations, starting with government-led projects and offering financial support, such as property tax rebates, to encourage private-sector participation. Raising public awareness of sustainability certifications can further increase demand, complementing financial incentives.

Cease et al. [120] identified four primary barriers to LEED-ND adoption: economic constraints, public awareness, organizational challenges, and policy limitations. Economic barriers arise when developers prioritize short-term financial gains over long-term sustainability benefits, while budgetary constraints limit government investment in certified projects. Public awareness barriers suggest that greater understanding of long-term benefits could reduce concerns about registration costs. Organizational barriers involve coordinating government units and balancing short-term gains with sustainability goals, while policy barriers, such as LEED-ND's strategic location prerequisites, may restrict developers. The study also highlights incentives like Tax Increment Financing Districts (TIFs) as key motivators for adoption, particularly in urbanized areas where certified projects are more common.

In their study, Morris et al. [121] combined qualitative and quantitative methods to examine barriers and incentives for adopting the Green Star Communities rating system. Their findings indicate that many stakeholders were unaware of the tool's initial version, with additional costs posing a significant barrier. Enhancing clarity about the tool's benefits and costs could encourage adoption, alongside a shift in industry perspectives to prioritize environmental stewardship for both intrinsic and financial reasons. The study emphasizes government initiation and funding as critical for successful project implementation, aligning with prior studies.

Table 5
Factors examined by FE studies.

Study	NSAT	Affecting Factors
Kochhar, Mahal [119]	GRIHA	Financial incentives
Cease, Kim [120]	LEED-ND	public funding
Morris, Zuo [121]	Green Star Communities	Improved marketing of the tool A fundamental behavioral change of industry members
Smith [122]	LEED-ND	Proximity to urban markets

Table 6
The existing incentives and mandates for the adoption of NSATs that align with India's national policy on climate change mitigation [119].

n	Incentive/ policy
1	Financial incentives
2	Ground coverage and FAR incentive
3	Mandatory compliance
4	Additional FAR/FSI incentive

Smith [122] conducted the inaugural study on FE research, examining the geographic distribution of registered projects. The author's findings indicate that the majority of projects are situated in densely populated urban cores, suggesting that proximity to urban markets is a crucial factor influencing the initiation and completion of LEED-ND projects. Therefore, the voluntary application of the tools by developers would result in a dichotomy within the country, whereby urban sustainability in less urban areas would be ignored, while urbanized states with a booming construction market would attract sustainable projects. Such spatial inequality would be an incremental result of the application of tools initiated to increase equity and sustainability, and therefore a mandatory policy for the application of NSATs would be necessary, at least for government projects.

3.1.6.1. Methodological considerations for FE studies. The key factors influencing NSAT adoption remain underexplored without comprehensive statistical analyses to evaluate the impact of various incentive policies on registration rates. Validating perceived barriers and success factors over time is essential for ensuring their reliability. Nearly two decades after the introduction of the first NSAT, CASBEE-UD, in 2006, FE studies could benefit from longitudinal approaches to assess the long-term impact of these factors. Integrating quantitative methods, such as regression analyses to measure policy effectiveness, with qualitative approaches, such as stakeholder interviews to capture contextual barriers, would enhance the robustness and applicability of FE research findings.

3.1.6.2. Suggestions for future FE researches. Identifying factors that influence NSAT adoption requires rigorous investigation, particularly given the limited focus on well-known frameworks like BREEAM-Co and CASBEE-UD (Table 6). Future FE studies should prioritize evaluating the effectiveness of these tools across diverse local contexts, such as varying regulatory or cultural environments, to help tool developers address context-specific challenges and enhance adoption in targeted markets.

To strengthen the reliability of identified barriers and success factors, FE studies would benefit from tracking real-world data over time. For instance, analyzing adoption rates following the release of new NSAT versions could provide insights into their practical impact. Integrating qualitative methods, such as in-depth stakeholder interviews, with quantitative approaches would offer a more comprehensive understanding of adoption dynamics.

3.1.7. RT 7 (DE): to design neighborhoods based on existing NSATs

DE studies focus on developing design principles or neighborhood plans based on the frameworks provided by Neighborhood Sustainability Assessment Tools (NSATs). Despite their limited presence in the reviewed literature, these studies are significant for translating NSAT criteria into practical design guidelines that address context-specific sustainability challenges. A key challenge arises when multiple NSATs developed for the same context prioritize different assessment parameters. For instance, Gangwar et al. [123] conducted a comparative analysis of three Indian NSATs—Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA), and Eco

Housing Assessment Criteria—to derive consolidated design principles. They organized the assessment criteria into ten focus areas, including site planning, energy conservation, and water management, which serve as the foundation for context-sensitive design guidelines.

3.1.7.1. Methodological considerations for DE studies. Developing design principles from multiple area-specific NSATs presents a methodological challenge, particularly when aligning diverse criteria and their respective weights. To ensure that design guidelines reflect the priorities of the local context, DE studies could prioritize criteria that carry higher weights in area-specific NSATs. Employing multi-criteria decision-making methods, such as the Analytic Hierarchy Process, may help balance conflicting priorities and produce robust, contextually relevant design principles.

3.1.7.2. Suggestions for future DE researches. context-specific design guidelines that address local environmental, cultural, and regulatory conditions. By translating NSATs, which often focus on end-product certification, into process-oriented design principles, these studies can support broader application by urban planners and certification applicants seeking to meet NSAT criteria effectively. For example, building on studies like Gangwar et al. [116], future research could prioritize developing guidelines over direct neighborhood design to enhance flexibility and applicability across diverse contexts.

3.1.8. RT 8 (PE): to introduce an existing NSAT

PE studies can be divided into two subcategories. The first subcategory of research aims to directly introduce NSATs [124,125]. However, some of these studies have been critiqued for adopting an affirming stance rather than maintaining a neutral analytical tone. For instance, Nielsen's study [124] on the UAE's ESTIDAMA tool opens by describing the UAE as "one of the most planned countries in the world." He continues with statements such as:

> *"Estidama is put forward as not just regulations or a rating method, but a vision and a desire to achieve a sustainable way of life in the region."*(p. 946)

While such aspirational language may reflect the policy intent, its use in academic writing typically requires support from empirical evidence or clearly stated sources. Additionally, the article does not include a defined methodology section outlining how these conclusions were derived.In contrast, the remaining subcategory of studies [126,127]. Present NSATs through descriptive analysis of assessment processes and frameworks. These works adopt a neutral tone, focus on technical accuracy, and refrain from subjective judgments.

3.1.8.1. Methodological considerations for PE studies. Some PE papers omit essential sections, such as the "research method," which are necessary for a scientific paper [124–126,128,129]. Steiner's 2020 presentation of the SITES rating system; lacks a methodology section, and other sections, such as the abstract, do not follow the principles of scientific writing, such as coherent presentation of objectives, methods, and findings [125].

Given that the impartiality of researchers may be a concern in such studies, it is recommended that authors clearly disclose the identities of the sponsors of PE researches. While sponsors have the right to expect high-quality, rigorous and useful research, it is essential to ensure that they do not impose recommendations that are not grounded in the data itself, nor do they influence the nature, content and conduct of the research through their personal research objectives [130]. Researchers should ensure that the impartiality of their work is reflected in all aspects of their studies. This should be evident either in the tone and content of the research itself or when presenting the results. It is therefore imperative that PE researchers present their results and conclusions based on documented data and through a methodologic process, as is the case with all research.

3.1.8.2. Suggestions for future PE researches. It is recommended that PE studies monitor updates to the same NSAT. It is essential to discuss the changes made in successive versions of the tool and the rationale behind those changes. This will provide insight into the priorities and perspectives of the tool developers over time.

Another issue that requires further investigation is the presentation of adapted versions of holistic tools for countries other than those in which the tools were originally developed. Cabrita and Alvarez [131] have discussed some of the main issues to be considered for adapting BREEAM-CO to the Spanish context. The description of an adapted version of holistic tools allows the reader to make a fair judgment about the conformity of the tools' assessment criteria with the contextual priorities. Such studies could also be considered as a starting point for IE studies.

4. Discussion

This systematic review establishes a novel typology of Neighborhood Sustainability Assessment Tool (NSAT) research by synthesizing 207 studies into eight research types (RTs) based on their objectives. It offers a robust framework to advance urban sustainability assessment. Unlike prior studies, which primarily focused on NSATs attributes—such as strengths, weaknesses, or cross-tool comparisons—this review adopts a meta-perspective by analyzing the literature itself through a thematic typology. It highlights methodological limitations and provides research-type-specific recommendations for future NSAT studies. The typology, which Bailey (1994) deems essential for advancing conceptualization, reasoning, language, and data analysis [132].

This typology highlights the multidimensional nature of Neighborhood Sustainability Assessment Tool (NSAT) research, reflecting both global standardization and local adaptation. AE studies (RT1), which employ tools like LEED-ND to evaluate urban developments, often assume their universal validity, neglecting context-specific features of Global South countries. However, numerous scholars have emphasized the importance of addressing intra-systemic spatial heterogeneity and local contexts in urban sustainability assessments [98,133,134]. Accordingly, DN studies (RT2) emphasize adaptability by developing Area-specific tools tailored to ecological, social, economic, and political settings. Similarly, IE studies (RT3) provide constructive critiques of existing tools' adaptability to diverse contexts. Literature review studies (RT4) solely encompass reviews of tool-related literature, while critical studies (RT5) question the sustainability of certified projects. FE studies (RT6) highlight adoption obstacles, such as financial constraints. DE studies (RT7) and PE studies (RT8), though less common, translate NSATs into design principles or introduce new tools [117], but often lack rigor and face significant critique.

Methodological shortcomings, prevalent across all research types (RTs), undermine the effectiveness and relevance of Neighborhood Sustainability Assessment Tool (NSAT) research. Overreliance on quantitative data and neglect of qualitative local priorities (RT1), inadequate validation (RT2), limited stakeholder engagement (RT3), overgeneralized limitations (RT4), cross-sectional designs (RT5, RT6), conflicting criteria (RT7), and bias (RT8) are prominent. Rooted in positivist, quantitative paradigms, these limitations hinder NSATs' ability to address urban system complexities, particularly in ecologically vulnerable Global South countries [88,135,136]. Scholars have previously highlighted issues such as failure to capture urban system intricacies [136], "quantifying the unquantifiable," overlooking uncertainties [137], biased criterion selection, and inability to systematically weight large sets of indicators by importance [138].

Unlike previous reviews, our analysis highlights not only tool-specific shortcomings but also methodological flaws in the underlying research practices. Its detailed, granular approach diverges from earlier

macro-level analyses, aligning with interdisciplinary calls for rigorous, systemic assessments.

The almost complete lack of longitudinal research in RT5 and RT6 limits our insight into certified projects' durability and adoption trends over time [117]. Likewise, the limited focus of investigative (IE) and presentation (PE) studies on updated NSAT versions [46] or their alignment with Sustainable Development Goals (SDGs) [102] overlooks these tools' policy potential in the context of accelerating urbanization.

A more in-depth analysis of the linkage between the typology and theoretical paradigms elucidates how each RT uniquely operationalizes Transition Theory, Adaptive Governance, and Socio-Technical Regimes to advance urban sustainability transitions. RT2 and RT7 align with Transition Theory's MLP by fostering niche-level experimentation, where NSATs introduce innovative metrics (e.g., social equity or urban resilience indicators) to challenge entrenched urban regimes, such as car-centric planning or fossil fuel-dependent infrastructures. These RTs drive transition pathways through multidimensional learning (technical, social, policy), network formation among stakeholders, and articulation of sustainability expectations, destabilizing regimes via strategic niche management [19–21]. RT1 embodies Adaptive Governance's polycentric, reflexive frameworks, enabling global south countries to adapt global standards (e.g., BREEAM Communities or CASBEE-UD) to local socio-ecological contexts, addressing challenges like climate vulnerabilities or socio-economic disparities through iterative stakeholder collaboration and self-organizing governance structures that enhance urban resilience [22,23]. RT3, RT6, and RT8 leverage Socio-Technical Regimes theory by positioning NSATs as boundary objects that facilitate knowledge co-production across sectors, navigating path dependencies (e.g., regulatory frameworks or market-driven urban planning) to reconfigure urban socio-technical systems toward sustainability [24,25]. RT5 integrates all three paradigms by scaling niche innovations (e.g., certified low-carbon neighborhoods) through adaptive governance processes while overcoming regime-level lock-ins, catalyzing systemic transitions via policy experimentation and stakeholder-driven innovation ecosystems [19,139]. This theoretically grounded mapping not only highlights NSATs' transformative potential but also informs policy by advocating for participatory governance platforms, longitudinal regime analyses, and AI-enhanced NSAT frameworks to align with global sustainability imperatives like the SDGs.

Regarding limitations, it can be noted that a systematic review based on retrospective and observational research designs may be subject to both systematic and random errors, as well as unexplained heterogeneity [140]. In addition to Dollman et al. (2021), other researchers such as Jüni and Egger (2005) [141], Yuan and Hunt (2009) [142], Zwahlen et al. (2008) [143], Järvholm and Bohlin (2014) [144], and Owens (2021) [145] have elaborated on these limitations in more detail. Although an in-depth discussion of these limitations is beyond the scope of this paper, potential limitations of this systematic review that should be considered by readers and editors include risks of bias such as publication bias, selection bias, data detection and extraction bias, attrition bias (patients lost to follow-up), and reporting bias. however, measures taken by the authors to address some of these limitations include Maintaining the integrity of the questions and purposes of the inquiry, utilizing electronic database and data management systems, searching in grey literature databases, employing two independent reviewers to extract and select articles, and using two screeners.

This study's focus on Scopus-indexed literature ensures methodological rigor and reproducibility but may exclude seminal works in neighborhood sustainability assessment (NSA) and urban assessment not captured in Scopus due to constraints in search criteria or temporal scope. Such omissions could constrain the typology's scope, potentially overlooking context-specific NSAT frameworks or alternative research types that enrich the classification. Future research should incorporate these works to refine and expand the RTs, ensuring a more comprehensive representation of NSAT scholarship and alignment with global sustainability objectives.

4.1. Policy implications

To address the reductionism, neglect of contextual features, and local needs and priorities in some Neighborhood Sustainability Assessment Tools (NSATs), it is critical for national governments and urban managers, particularly in the Global South, to establish legal frameworks and allocate adequate national and local budgets. These legal base and funds should support the creation of NSAT innovation funds and centers, as well as R&D for adaptive, customized NSATs. These adaptive and customized NSATs should be piloted in "neighborhood sustainability laboratories" to validate their effectiveness, efficiency, and relevance before large-scale implementation [13].

To enhance the impact of NSATs, policymakers must promote and support the integration of artificial intelligence (AI), Internet of Things (IoT), and machine learning in developing smart NSATs [146], particularly in rapidly growing and transforming cities and neighborhoods, such as those in Asia and Africa. Key functionalities include: (1) establishing "self-regulating sustainable zones" with digital dashboards for real-time monitoring [28]; (2) identifying actual neighborhood behaviors and needs using IoT sensor data [147]; and (3) launching "NSAT co-creation networks" powered by blockchain technology to involve local stakeholders and marginalized groups in designing indicators [92,148,149]. These capabilities address gaps in current NSATs by enhancing responsiveness and inclusivity.

We also recommend 'gamified' sustainability certificates that reward residents-via digital points-for behaviors like reduced energy use [150]. This approach fosters community participation and addresses gaps in social engagement within current NSATs. Additionally, policies should encourage developers and builders to adopt these tools through incentives, including tax exemptions, subsidies, or enhanced marketing opportunities. By fostering collaboration among governments, organizations, and stakeholders, a robust platform can be created to support the development and implementation of NSATs, ultimately paving the way for a more sustainable and resilient urban future [77,79].

Singapore's mandatory Green Mark for Districts, administered by the Singapore Building and Construction Authority (BCA), is a good example of government efforts to encourage NSA adoption. This top-down policy of making NSATs mandatory in some specific areas (e.g. Marina Bay) [151], combined with tax incentives [152,153], has encouraged the private sector to get involved. Thus, even in a developed country like Singapore, the promotion of NSAT is a result of both optional and mandatory policies.

5. Conclusion

Over the past two decades, Neighborhood Sustainability Assessment Tools (NSATs) have undergone considerable evolution. The introduction of CASBEE-UD in 2006 marked a significant turning point in the construction industry. The development of these tools has been driven by the urgent need to address sustainability challenges in urban environments, emphasizing the importance of integrating environmental, social, and economic considerations into neighborhood development. As the global focus on sustainability intensifies, it becomes increasingly clear that the contributions to NSATs will be crucial in guiding urban planning and design towards more sustainable and resilient outcomes. NSATs should be more dynamic and address emerging sustainability concerns (e.g. smartness, resilience, etc.) in their indicators [111] and at the same time, address the local context issues [10,111,133].

In summary, our eight RTs offer a structured lens through which to understand past NSAT research and to guide future investigations. Table 7 summarizes the main findings in each RT, highlighting the priority questions for future studies, the methodological shortcomings that should be addressed, and the key methodological considerations that should be given greater attention. This exhaustive examination

Table 7
The key considerations for authors conducting research on the eight RTs.

	RT	Sub types	Preferred issues to be address	Methodological considerations
1	AE Application of NSATs to measure the sustainability of:	Existing developments Planning approaches Proposed neighborhood layouts	The ability of planning approaches to be applied for different cases, gives it a priority; i.e. urban regeneration policies.	Adopting a critical approach to NSATs rather than an affirmative one; AE studies must acknowledge that NSATs cannot be directly applied in countries other than the one for which they have developed; A realistic approach would be to benchmark the international NSATs against local standards of developing countries before applying them. Due to verify the western NSAT assessment results in developing countries; qualitative methods (i.e. stakeholder interviews) must be applied.
2	DN To develop a new NSATs or enhance existing tools	Site-specific tools Topic-based tools Area-specific tools Holistic tools	Strategic issues of developing countries must be identified and addressed by DN studies. NSATs should be developed for higher polluting and emitting countries. Shortcomings in covering sustainability aspects equally should be addressed	DN studies have three steps: Step 1: applying in-depth qualitative methods (e.g. stakeholder interviews) will help identifying unique urban challenges of each context and choosing relevant indicators; but due to the financial and time constraints; consensus methods (especially Delphi) can be an efficient alternative. Step2: When assigning weights to the indicators, it is recommended to use MCDM methods that consider the linkages between indicators, such as ANP. Step3: Validating an NSAT is a time-consuming process requiring empirical studies to assess certified developments in practice. A more reliable initial validation can be achieved by evaluating the same project with both an existing tool and the proposed tool, allowing differences in results to be explained based on contextual factors reflected in the proposed tool's indicators and weights.
3	IE To investigate the existing tools	Site-specific investigation Topic-based investigation Area-specific investigation Holistic investigation	Successive versions of existing tools should be examined and compared. - Area-specific investigations seek for the ability of NSATs to reflect the contextual issues and local nuances in their assessment framework.	A qualitative approach to Area-specific investigations should not be limited to content analysis of NSATs' frameworks. Other methods, such as in-depth interviews, should be used to identify the key urban challenges and development concerns of each context.
4	RE To review the related literature on NSATs	–	RE studies can enhance readers' contextual understanding of how global sustainability agendas shape NSAT development.	-RE researchers should aim to avoid overgeneralizing findings from specific NSATs to all such tools. -Applying a critical approach to the reviewed studies, RE researches should engage with the quality assessment of reviewed studies.
5	IC To investigate certified developments	–	-Focusing on qualitative issues in addition to quantitative ones - Studies must consider the effect of external forces on the socio-economic success of the certified projects in a sustainable manner.	Narrowing down the qualitative issues (e.g. walkability) to measurable matters is a methodological fallacy that should be avoided. Deep interviews and field researches instead of close-ended or single word answer questionnaires must be applied for evaluation of the qualitative issues. The need to transition from cross-sectional investigations to longitudinal assessments must be acknowledged by IC researchers.
6	FE To identify factors affecting	–	-Long term documented studies to investigate the	-The need to apply both quantitative and qualitative methods in an

(*continued on next page*)

Table 7 (*continued*)

	RT	Sub types	Preferred issues to be address	Methodological considerations
	the adoption of NSATs		real impact of perceived barriers and success factors - Studies should evaluate the effectiveness of holistic tools in various local contexts	interwoven manner would be the most urgent methodological requirement of such researches (to identify the perceived barriers and real constrains). -FE researchers must acknowledge the need to transition from cross-sectional investigations to longitudinal assessments so they can evaluate the effectiveness of incentives on NSAT adoption over time.
7	DE To design neighborhoods based on existing NSATs	–	-Future DE studies should focus on establishing design principles rather than just designing neighborhoods	Application of multi-criteria decision-making methods to extract the main design principles from the criteria of different NSATs developed for the same context.
8	PE To introduce an existing NSAT	Studies that directly introduce NSATs Studies that indirectly present NSATs.	-PE studies should monitor updates to the same NSAT. - The presentation of adapted versions of holistic tools for countries other than those in which the tools were developed	-The dominance of an affirmative approach over an unbiased one is a methodological problem of such studies. -The researcher's impartiality must be reflected in the unbiased tone of the study's different sections.

serves as a roadmap for researchers and tool developers, guiding them in addressing the identified gaps and enhancing the effectiveness of NSATs with respect to the objective of sustainable urban development.

The linkage between this typological classification and theoretical paradigms underscores NSATs' transformative potential for urban sustainability transitions. RT2 and RT7 harness Transition Theory's Multi-Level Perspective to advance innovative NSAT metrics, challenging unsustainable urban regimes like fossil fuel-dependent systems [20,21]. RT1 aligns with Adaptive Governance, enabling global NSATs (e.g., BREEAM Communities, CASBEE-UD) to adapt to local socio-ecological contexts, enhancing urban resilience [22,23]. RT3, RT6, and RT8 draw on Socio-Technical Regimes, positioning NSATs as tools to overcome institutional barriers and reconfigure urban systems [24,25]. RT5 integrates these paradigms to scale sustainable urban innovations [139]. Future research should develop context-sensitive NSATs, leveraging longitudinal niche-regime analyses, participatory governance models, and AI-driven assessment tools to align with global sustainability goals like the SDGs.

In addition, future studies should prioritize several key directions. DN studies should focus on developing Area-specific NSATs, leveraging multi-criteria decision-making (MCDM) methods to address indicator interlinkages. AE and IE studies should actively engage stakeholders and integrate qualitative, context-specific data. Longitudinal IC and FE studies should employ mixed, abductive methods to identify success and failure factors in certified projects and distinguish real from perceived adoption barriers. RE studies should analyze specific NSATs (e.g., BREEAM Communities) to pinpoint tool-specific limitations and success factors, linking their evolution to global events like SDG adoption. DE studies should develop context-sensitive design guidelines to support applicants and deter "credit-hunting" by refining indicator weights. PE studies must monitor NSAT updates with evidence-based, impartial, and transparent reporting, disclosing funding sources.

CRediT authorship contribution statement

Behrooz Biqaraz: Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mahmoud Ghalehnoee:** Writing – review & editing, Validation, Methodology. **Hassan Mohammadian Mosammam:** Writing – review & editing, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2025.101173.

Appendix A

(TITLE-ABS-KEY ("Neighb*rhood sustainability rating system") OR TITLE-ABS-KEY ("urban sustainability assessment tool") OR TITLE-ABS-KEY ("Neighb*rhood sustainability assessment tool") OR TITLE-ABS-KEY ("Neighb*rhood sustainability certification system") OR TITLE-ABS-KEY ("urban sustainability rating system") OR TITLE-ABS-KEY ("LEED-ND") OR TITLE-ABS-KEY ("LEED for Neighborhood Development") OR TITLE-ABS-KEY ("BREEAM Communities") OR TITLE-ABS-KEY ("CASBEE-UD") OR TITLE-ABS-KEY ("Green Star Communities") OR TITLE-ABS-KEY ("Pearl Community Rating System") OR TITLE-ABS-KEY ("IGBC Green Townships") OR TITLE-ABS-KEY ("Global Sustainability Assessment System") OR TITLE-ABS-KEY ("DGNB for Districts") OR TITLE-ABS-KEY ("DGNB-NSQ") OR TITLE-ABS-KEY ("GBI Township") OR TITLE-ABS-KEY ("BCA Green Mark for districts") OR TITLE-ABS-KEY ("BERDE") OR TITLE-ABS-KEY ("Sustainable Building Tool") OR TITLE-ABS-KEY ("SBTool") OR TITLE-ABS-KEY ("Building Environmental Assessment Method (BEAM) Plus Neighbourhood Assessment Tool") OR TITLE-ABS-KEY ("ITACA Protocol Urban Scale") OR TITLE-ABS-KEY ("Assessment Standard for Green Eco-districts") OR TITLE-ABS-KEY ("Envision sustainab*") OR TITLE-ABS-KEY ("ESTIDAMA")).

Appendix B

(TITLE-ABS-KEY ("HQE2R") OR TITLE-ABS-KEY ("EnviroDevelopment") OR TITLE-ABS-KEY ("STAR Communities") OR TITLE-ABS-KEY ("Neighborhood Sustainability Framework") OR TITLE-ABS-KEY ("EarthCraft Communities") OR TITLE-ABS-KEY ("One Planet Communities") OR TITLE-ABS-KEY ("AQUA Bairro e loteamento label") OR TITLE-ABS-KEY ("EcoDistricts") OR TITLE-ABS-KEY ("Green Township Index") OR TITLE-ABS-KEY ("Green Rating for Integrated Habitat Assessment") OR TITLE-ABS-KEY ("Sustainable Community Rating") OR TITLE-ABS-KEY ("EcoQuartier") OR TITLE-ABS-KEY ("2030 Districts") OR TITLE-ABS-KEY ("Assessment Standard for Green Eco-districts") OR TITLE-ABS-KEY ("BEAM Plus Neighbourhood") OR TITLE-ABS-KEY ("Neighborhood Assessment Tool") OR TITLE-ABS-KEY

("Comprehensive Assessment Method for Sustainable Urban Development") OR TITLE-ABS-KEY ("Circles of Sustainability") OR TITLE-ABS-KEY ("Conavi CEV Mexican Code") OR TITLE-ABS-KEY ("EEWH Assessment System for Eco-community") OR TITLE-ABS-KEY ("Enterprise Green Communities") OR TITLE-ABS-KEY ("Green Star SA") OR TITLE-ABS-KEY ("GreenTRIP") OR TITLE-ABS-KEY ("Living Community Challenge") OR TITLE-ABS-KEY ("Successful Neighborhood Model") OR TITLE-ABS-KEY ("Sustainable Project Appraisal Routine") OR TITLE-ABS-KEY ("Sustainable Sites Initiative") OR TITLE-ABS-KEY (vicurban AND sustainability AND charter) OR TITLE-ABS-KEY (master AND planned AND community AND assessment AND tool) OR TITLE-ABS-KEY ("Wulvern Indicators of Neighborhood Sustainability")).

Data availability

Data will be made available on request.

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