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Urban sustainability Implementation and Indicators in the United States: A systematic review

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Review Articles

Urban sustainability implementation and indicators in the United States: A systematic review

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ABSTRACT

Urban sustainability is the goal of many cities in the world, yet very few have achieved a level of sustainability that goes beyond the most basic environmental objectives. The practice and assessment of sustainability implementation are greatly compounded by lack of funding, technical know-how, political will, and the power disparity between dominant institutions and marginalized communities. This systematic analysis of urban sustainability literature involved the review of 241 studies published between 2010 and 2022. We critically examined current debates and challenges in urban sustainability, identifying gaps and opportunities and providing recommendations for creating equitable, just, and sustainable urban futures. We also reviewed 23 studies to summarize the social, ecological, and technological systems (SETS) indicators used to measure urban sustainability in the same period, many of which may not be relevant to the lived experiences of marginalized communities. To move toward more meaningful and equitable pathways, it is important to develop SETS indicators of urban sustainability that are reflective of the experiences and priorities of diverse groups in society. This review identifies four major issues in the current urban sustainability literature: space, scale, stakeholders, and dimension. These issues need to be centered in sustainability planning in order to develop solutions that are appropriate for the local context.

Introduction

Sustainability is described as the practice of meeting the needs of the present without jeopardizing the ability of future generations to meet their own needs [6,96]. Urban sustainability is, therefore, the practice of sustainability in cities and is characterized by several dimensions such as society, economy, and the environment [51,65], or society, culture, economy, and ecology [64,160]. While there is general agreement among scholars on the concept of urban sustainability, the approaches to achieving it vary because of differences in focus, scale, and environmental, geographic, political, and socioeconomic contexts (Table 1). Urban sustainability encompasses ideas about opportunities for economic development, social progress, environmental conservation, and, more recently, about social justice [2,3].

Several countries around the world have promoted urban sustainability as a core agenda in recent decades. In the early 2000s, the Canadian federal government formulated a *new deal* for cities and communities to achieve sustainable outcomes [22]. Similarly, many nations in the European Union implemented urban sustainability programs covering social, economic, and environmental dimensions in the 2000s [77]. The Indian government launched a national smart city mission in 2015 [63,156], which is described as a way to "drive economic growth and improve the quality of life of people by enabling local development and harnessing technology as a means to create smart outcomes for citizens" [78]. China has incorporated several socioeconomic and environmental sustainability indicators into its government policy in pursuit of administrative and political goals [93]. Within the United States of America (USA), national studies have shown that cities view and implement sustainability in different ways [134,149,158]. For example, in New York City, the "One NYC" plan aims to create a more sustainable and equitable city through a range of initiatives such as reducing greenhouse gas emissions, improving air quality, increasing access to green spaces, and promoting social justice. Seattle, Washington has implemented a range of initiatives to promote sustainable transportation, such as building out a network of bike lanes, promoting electric vehicles, and expanding public transportation options. Thus, understanding the local context in which sustainability is designed and implemented is important for identifying specific sustainability

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Table 1
Various definitions of urban sustainability.

Definition	Author/ Organization
A sustainability city has the following components: "minimizing the consumption of space and natural resources; rationalizing and efficiently managing urban flows; protecting the health of the urban population; ensuring equal access to resources and services; maintaining cultural and social diversity."	[133]
A sustainable city is "one which succeeds in balancing economic, environmental and socio-cultural progress through processes of active citizen participation."	[160]
Urban sustainability is "the process of developing a built environment that meets people's needs whilst avoiding unacceptable social or environmental impacts."	[58]
Urban sustainability is "an adaptive process of facilitating and maintaining a virtual cycle between ecosystem services and human well-being through concerted ecological, economic, and social actions in response to changes within and beyond the urban landscape."	[155]
Sustainable urbanization is the creation and maintenance of safe, inclusive, resilient and sustainable cities and human settlements, enabling all residents to access opportunities for prosperity and well-being, while protecting the environment and natural resources	[139]
Urban sustainability is an adaptive process of addressing economic (e.g., economic equity), social (e.g., resilience to climate change impacts), environmental (e.g., reduced air pollution) and governance (e.g., ensuring citizens' active participation in carrying out urban functions) issues in an integrated way within and beyond urban areas	[49]

indicators in cities.

As the understanding of sustainability varies, so do the priorities of planners. Urban sustainability is subject to a range of institutionalized structures and behaviors, such as policies and regulations, that can impact its implementation and variability. However, cities possess inherent resilience through a variety of social, spatial, technological, and ecological characteristics, as well as through support from socio-political networks and the benefits of environmentally conscious practices like smart city development [119]. Despite these strengths, implementing sustainable practices can be challenging due to the interdependent and interconnected nature of the behavioral, organizational, and institutional frameworks of agencies responsible for sustainability implementation at multiple levels of governance [54,154]. Cooperation and coordination between different agencies and organizations are required to resolve many of these challenges. There are also concerns regarding the level of coordination required in the policy and planning realm to achieve sustainability, particularly in the absence of an official or regulatory framework in many jurisdictions. This is especially true in capitalistic Western nations such as the United States, where there is a distinction between local, regional, and national priorities, that ultimately prioritize private, for-profit interests. Therefore, the question of achieving sustainability in cities is crucial to not solely to addressing policy and implementation inertia on multiple scales but to improving the quality of life for people (i.e. promoting access to clean water and air, reducing traffic congestion, expanding green infrastructure); scaling economic development and innovation (such as new business opportunities in areas such as renewable energy, waste management, smart buildings, and sustainable transportation); and ensuring equity and social justice for current and future generations [14,52,66,124,127,130].

The main objectives of this review article are to summarize the recent advancements in urban sustainability implementation and identify indicators influencing the implementation of urban sustainability in the United States across the social-ecological-technological system's (SETS) framework. The review article is divided into four sections: (i) an introduction to the concept of urban sustainability; (ii) the American urban sustainability discourse and the main factors influencing implementation in the US; (iii) the role of SETS indicators in sustainability measurement that aid its implementation; and (iv) summary and future research directions. We used review studies from January 2010 to December 2022 to summarize the state of urban sustainability discourse. This study seeks to expand the urban sustainability discourse within the framework of equity and building adaptive capacity at the city scale while attempting to answer the following questions: (i) What are the major issues in urban sustainability implementation in the US?(ii) What are the major social, ecological, and technological urban sustainability indicators and how do they intersect with the major issues in urban sustainability implementation?

Literature review

Numerous scholars have attempted to quantify sustainability for ease of implementation and to establish best practices in governance [7,83,91,113,128,131,143]. These efforts have centered on socioeconomic, environmental, and technological dimensions. At the same time, there have been ongoing urban reforms aimed at transforming modern cities into smart cities, which are defined by the United Nations as "an integrated system of people, products, processes, information, and assets" (Sustainable Development Goals 100) [139]. A smart city requires both technological and information systems to achieve sustainability [9]. Indeed, urban sustainability governance has been increasingly expanding beyond environmental concerns to encompass economic, social, and technological aspects [113]. However, relevant policies and measures for smart cities remain limited and often poorly governed by most local governments [54,132]. In light of these challenges, it is crucial to view sustainability implementation not only from socioeconomic and environmental dimensions, as traditional sustainability measures tend to do, but also from the standpoint of creating and maintaining a more resilient infrastructure that supports economically challenged and ecologically fragile urban centers.

Indicator-based systems are popular methods for assessing critical sustainability programs in cities. One of the earliest methods is the pressure–state–response (PSR) framework, which uses current pressures and/or driving forces to identify indicators [61]. Pressures refer to human activities (e.g., population growth, urbanization) or natural events (e.g., floods, hurricanes) that create stress on the environment. They are the drivers of environmental change and can occur at different levels, such as global, regional, and local. Indicators to inform sustainability are also organized into themes and dimensions such as the environment, economy, society, technology, and institutions [33]. Other indicator systems may use a single composite indicator, such as the ecological footprint (EF), environmental performance index (EPI), or human development index (HDI). Such indicator systems are often policy driven. As policies are implemented, urban municipalities and government agencies are eager to learn from their outcomes and share their successes and failures with other municipalities [140]. However, existing sustainability assessment methods fail to provide mechanisms that effectively address the needs of these municipalities, particularly because indicators do not reflect local needs and sentiments if they are not chosen carefully. In addition, borrowing indicators from literature and/or other jurisdictions and applying them directly may result in a false sense of success in domains and adversely impact community trust and resilience. Kaur and Garg [70], for instance, highlighted that the method used to measure the sustainability of selected cities often fails to accurately reflect the complexity and diversity of the underlying issues, indicating that successful programs cannot be easily replicated without localizing the method first. Thus, a need exists for a new framework that can create locally specific indicators using methods and actors uniquely qualified in their fields to create them.

Data and methods

Data

We used 241 peer-reviewed papers for the analysis of urban sustainability literature and additional 23 peer-reviewed papers that applied urban sustainability indicators in the United States. These papers were identified using ScienceDirect, *a leading* bibliographic database offering greater accuracy in results and an overall better search engine compared to other databases such as *Google Scholar* [50,57]. The process of selecting these papers is described in the method section.

Methods

Urban sustainability issues

The keyword search was conducted using ScienceDirect®, and the combination of combined search words included were as follows: USA, urban sustainability indicators, urban sustainability, United States of America, and cities. The initial search resulted in 2783 studies published between 2010 and 2022. We employed a PRISMA approach to develop a checklist of items for reviewing articles, which helps develop a clear set of exclusion criteria. PRISMA provides a systematic review checklist of items that must be reported [120]. All review articles and those that did not have a geographic focus in the United States were excluded based on title and abstract screening (Fig. 1). Further, we excluded articles that do not specific urban sustainability focus, resulting in 241 articles.

Based on a literature review of these 241 papers, we identified four major issues associated with urban sustainability implementation. They are related to "Dimension", "Scale, "Space, "and "Stakeholder". The issues were identified using the abstract, keywords, and primary research questions. "Dimension" refers to studies that focused on a particular theme of sustainability such as environmental promotion or social equity. "Scale" refers to studies that prioritized the scale of the analysis such as neighborhood or city as central to their research. "Space" includes studies that empirically analyzed, for example, the distribution of resources over space. Finally, 'stakeholder' refers to studies that engaged or included stakeholders in some capacity. Indeed, some of the studies in our analysis focused on multiple issues, and we created a database that we counted separately for each issue the paper focused on. Hence, the total number in some years contains repetitions because some studies have multiple focuses.

As shown in Fig. 1, spatial issues dominated the urban sustainability discourse in the study period, closely followed by dimensional issues, whereas stakeholder and scale issues were relatively less focused. However, all four themes showed an upward trend since 2020.

SETS urban sustainability indicators

This study explicitly frames urban sustainability as a multi-causal and multi-scale process, in which stakeholders play a key role in defining a balance between several dimensions that may be categorized as "social," "ecological," and "technological" systems, or the SETS [27,28]. We empirically focus on quantitative studies that assess the relationship between urban sustainability and various urban sustainability indicators. These objectives will aid the formulation of more appropriate policies and strategies for sustainable and equitable urban development in the United States.

A systematic literature review was conducted using the ScienceDirect database. The search timeline was January 2010 to December 2022. The search terms included the keywords urban sustainability indicators, "urban sustainability indicators, social sustainability, ecological sustainability, technological sustainability, usa". The exclusion criteria followed a PRISMA approach and were as listed below: papers published before 2010, papers that were not original research articles, and papers that were not peer reviewed. We also excluded papers that did not focus on US cities in the final round. A total of 1593 articles were produced, of which 23 were included for the purpose of this review after carefully applying each exclusion criterion (Fig. 2).

Results and discussion

Issues related to dimensions

Sustainability practices can be categorized into several dimensions. Studies have largely focused on social, economic, infrastructure, and environmental factors [71,143,152], but some have also focused on economic and political factors [30,45,126]. Previous studies prioritized environmental factors [24,29], notwithstanding criticism of the dominance of environmental policies within the sustainability narrative [104,105,129,158]. Indeed, several empirical studies have reported that social sustainability and other forms of sustainability are neglected or underemphasized in larger sustainability initiatives [35,47,69,105]. Similarly, technological sustainability is under-emphasized, although it is indispensable for achieving smart city goals [67,72]. For various definitions of the different dimensions of sustainability, see Table 2.

Increasing policy and economic interventions in environmental sustainability seem to disregard the need for social and other forms of sustainability, and the predominance of a narrow vision of environmental sustainability neglects other dimensions [146]. Although

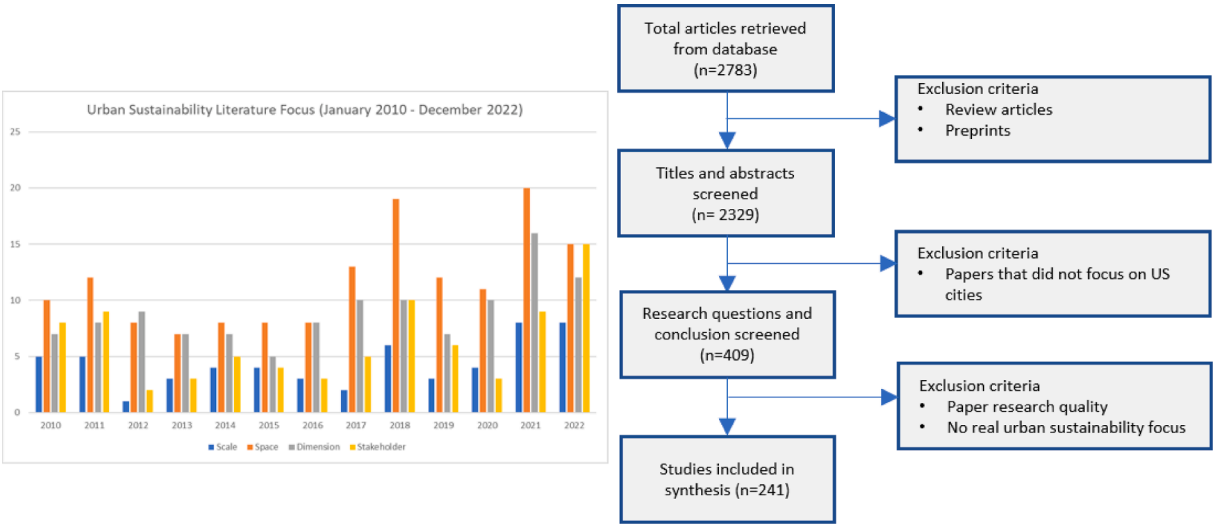

Fig. 1. Urban Sustainability literature focus between 2010 and 2022.

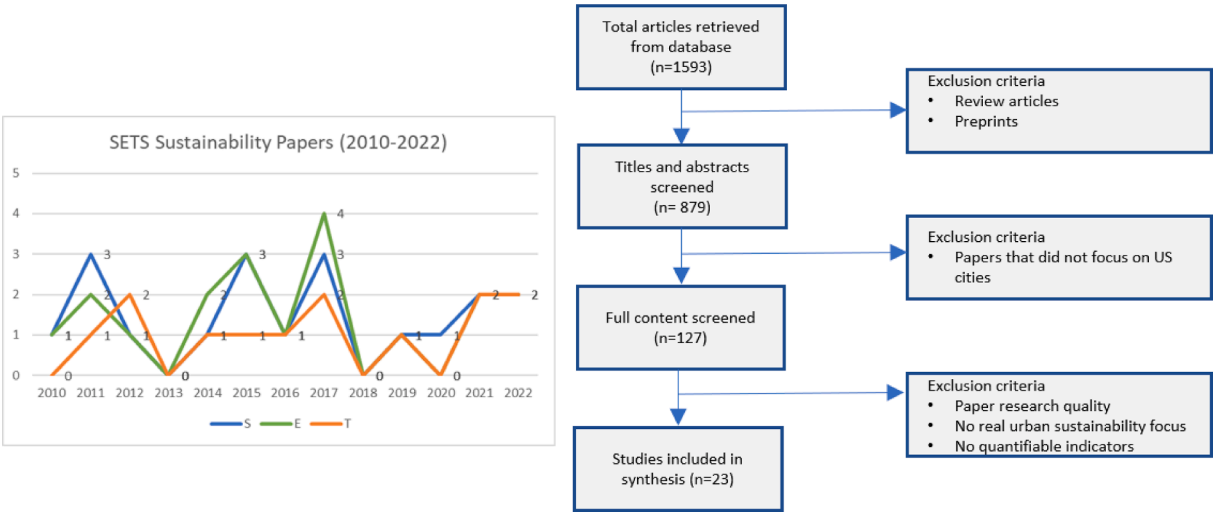

Fig. 2. Urban Sustainability Indicator papers published in the US, 2010–2022 and systematic flowchart.

Table 2
Various definitions of social, environmental, and technological sustainability.

Sustainability	Definition	Reference
Social Sustainability	*Social sustainability can be defined as specifying and managing both positive and negative impacts of systems, processes, organizations, and activities on people and social life*	[11]
	Social sustainability (SocSus) is defined as a measure of human welfare.	[99]
	Like the concept of sustainability, social sustainability is neither an absolute nor a constant. Social sustainability has to be considered as a dynamic concept, which will change over time (from year to year/decade to decade) in a place.	[40]
	Social sustainability occurs when the formal and informal processes, systems; structures; and relationships actively support the capacity of current and future generations to create healthy and livable communities.	[162]
Environmental Sustainability	*Environmental sustainability could be defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity*	[101]
	Environmental sustainability covers a wide range of issues starting from a specific location to global	[39]
Technological Sustainability	*Technological sustainability may be summarized as efforts to progress through development and innovation, but without forgetting to consider the respect of natural resources*	[142]
	A coherent urban development strategy developed and managed by city governments seeking to plan and align in the long term the management of the various city's infrastructural assets and municipal services with the sole objective of providing the quality of life for the citizens.	[44]

different dimensions of sustainability are independent, they are also sufficiently interconnected to require combined intervention [43,84,123]. Therefore, separate interventions in different dimensions are less likely to result in overall sustainable evolution in cities. Studies have shown that achieving social sustainability can significantly increase the long-term effectiveness of environmental policies [47,82]. While outcomes are not guaranteed in the social domain, the idea is to offer equal opportunities across critical social sustainability initiatives, such as education, employment, housing, and health. Similar interventions are undoubtedly needed in the environment domain, despite its dominance, to mitigate the risk posed by climate change and to ensure environmental justice. Examples include clean water access, fair distribution of common natural resources, such as trees and parks, and better pollution management. In the technological domain, improving Internet access, providing clean energy, and reliable transportation options more equitably are clearly some of the priorities [138]. The lack of recognition and integration of socioeconomic and technological interests is problematic for successful implementation of urban sustainability [100].

Spatial issues: social and environmental justice

Spatial issues in sustainability implementation take many forms worldwide and is driven by a variety of global factors including population growth, migration, poverty, religion, class, race, and other socioeconomic and environmental factors [21,75,145]. Regionally, historical and current geopolitical, economic, and environmental factors also contribute to spatial issues [153]. At the local level, spatial issues are a result of a combination of global and regional factors, as well as local factors such as local culture, political climate, and economy, among other factors. These factors are all encompassed within the broader concept of environmental injustice, which manifests as imbalances in access to resources, exposure to pollution, and vulnerability to climate change impacts. The environmental justice concept broadly covers three types of justice [135]: distribution, procedure, and recognition. Procedural justice advocates fairness in procedures (especially bureaucratic procedures) that often makes it harder for people of color and other marginalized communities to participate in decision making and to access public services. Distributive justice demands fairness in terms of resource distribution. Recognition or sense of justice refers to the equal treatment of all people and the recognition of their cultures and identities and implementation of efforts to rectify historical inequities [62].

Urban policies in the US, such as redlining and exclusionary state and municipal laws, have historically led to the segregation of communities and created a poor quality of life for the most marginalized sections of society [23,111]. The legacy of historic policies has continued to haunt today's population in all major cities [4,161], covering various types of

injustices. As a challenge to sustainability implementation, the lack of valuable environmental resources such as trees [42,46,125] and parks [106] exacerbate environmental injustice in urban communities. Simultaneously, the sudden introduction of such resources has adversely affected racial and economic minorities in urban communities (e.g., green gentrification) [4,56]. Consequently, evidence of the successful implementation of sustainable policies in urban areas is mostly limited to wealthier sections of the majority community and their community organizations [8]. The potential of green gentrification is well established, but questions remain regarding how a permanent, long-term shift to the green sector will affect those living in poverty, who must deal with both the direct impacts on their lives and the impacts of gentrification upscaling, such as building/structure demolition and new development. To this end, scholars have proposed different solutions, ranging from the integration of social, ecological, economic, and technological sustainable systems [76] to sustainable degrowth [92] and color-blind environmental justice interventions to benefit low-income groups. If the discussions on social justice have been contradictory, the calls from some activists for government incentives towards sustainable development have also seemed unclear, as it is difficult to measure the actual impact on opportunities and eventually on sustainable development outcomes [59]. We assert that the lack of clarity in this scenario is partly due to the limits of social movements' ability to enforce long-term legal and financial measures toward governments, which have policymakers elected by the general population. These policymakers can be indecisive for reasons such as social and political pressures; only through the active participation of the public and the cultivation of general consensus can the existing mechanisms be leveraged to yield significant change.

The disproportionate distribution of hazardous waste sites in the US affects Indigenous and African American communities, as was originally shown in the United Church of Christ's report [26], and subsequently confirmed by several studies [32,48,147,148]. Environmental justice in US cities is closely linked to race, and race is the best predictor of environmental injustice [98]. Therefore, the term "environmental racism" is suggested as a more appropriate term for environmental injustice [25,26]. Examples of environmental racism can be found in cities such as Flint, Michigan, a majority-Black city, where municipal drinking water is contaminated with lead and bacteria [115]. Similar issues have been found in Benton Harbor, Michigan, another Black-majority city (85% Black), where complaints about lead contamination have not been resolved [85]. In contrast, neighboring predominantly white communities have safe drinking water. These examples highlight the consistent denial of distributive, procedural, and recognition justice to people of color and how inadequate interpretation of the environmental justice framework may create false notions of success within the field. Environmental justice is complex because it involves not only the distribution of resources and services, but also the distribution and recognition of identities and cultures. If we limit the scope of environmental justice to resource distribution alone, we can cause more harm than good. Understanding the various dimensions of sustainability requires using a systems perspective instead of a simple focus on resource distribution, which subsequently requires more inclusive socioeconomic development strategies. Indeed, recent studies have applied the Social-Ecological-Technological Systems (SETS) framework for this reason, in addition to the fact that society is now more integrated along these lines than ever before [90].

Issues related to stakeholder engagement

Sustainability implementation in cities is also affected by how communities participate in the process and how they are engaged in implementing sustainability initiatives. Evidence has shown the importance of inclusive and participatory processes for effective sustainability implementation [53,68,81]. Studies have consistently highlighted the importance of knowledge co-production in urban governance [122]. The co-production of knowledge can also improve community perceptions of government policies [15,108]. Effective participation can only occur when the public participation process is aligned to the local context and needs with all stakeholders meaningfully involved, their voices heard, and there is a high level of trust [36]. Involving the public can ultimately increase the knowledge base and provide legitimacy to sustainability policies while facilitating their implementation [74]. For instance, Benner and Pastor [13] showed that when cities focus on social equity, they may contribute to economic growth and resilience through examples from Salt Lake City (UT), Oklahoma City (OK), and San Antonio (TX).

Implementing participatory budgeting in Chicago, IL [150] and Phoenix, AZ [34] resulted in increases in both residents' perceptions of their city and the bond rating, while improving community engagement. As a result, 23 jurisdictions across the US introduced participatory budgeting between 2009 and 2018 [60, 88,121]. While participatory budgeting has the potential to improve citizen participation and build community engagement, its implementation is limited in several ways (e.g., available resources, community interest, and government outreach), especially if the participatory process is overwhelmed by vested interest groups. Other forms of community engagement may exist in the form of community stewardship, as in the case of the *Community Watershed Stewardship Program* in Portland, OR [94].

Overall, community engagement measures include greater citizen control, greater participation from low-income communities, and community engagement including change agents and citizens themselves. This suggests that the community engagement process is a two-way street; community engagement can only be successful if the community itself is actively involved, but there is a lack of process to enable citizens to participate in their own oversight in many jurisdictions [18,79]. For a successful community engagement process, the right tools must be employed - the 'right tools' for the task may differ from project to project. The 'right tools' also depend on the scale. Notwithstanding, there is overwhelming evidence in the literature that community engagement is an effective tool for implementing urban sustainability, although its overall success depends on the stakeholders, community participation, tools, and processes employed by the projects. An important conclusion based on the literature review is to strengthen and improve the processes of community engagement and implement appropriate tools that can be achieved through sociocultural and community studies.

Socio-politically, there is a lack of integration of indigenous knowledge into sustainability practices. Prior to the arrival of European colonizers, indigenous communities lived in harmony with nature using accumulated wisdom from previous generations. The native communities not only managed to preserve their culture through the tradition, religion, and spirit of the place but also incorporated the knowledge of sustainability into their daily lives [136]. However, the modern US sustainability discourse mostly ignores indigenous sustainability knowledge in theory and practice [89]. Even when elements of indigenous knowledge are incorporated, recognition is not given to indigenous origins [97]. The United States evolved with the notion that indigenous intellectual property was unnecessary for social, political, and ecological functions. These modern assumptions need to be challenged if the overall situation of indigenous communities is to improve in the US and beyond. The distributive, recognition, and procedural injustices that indigenous peoples experience worldwide depict the same 'structure of bad faith' on a world scale that many observers have proposed exists between indigenous peoples and developed countries [12,36,73]. This bad faith structure is institutionalized in the relationship that developed countries have with their modernizing indigenous populations, which are at best unequal.

Beyond this inequality, the lack of familiarity with tribal knowledge outside of their communities and the political and economic constraints faced by Sovereign Native American Nations have hindered the incorporation of their knowledge into municipal governments' urban sustainability programs, preventing large-scale replications. There are no

large cities on so-called reservations; for example, Tuba, the largest community within the Navajo Nation, has a population of 8,070, as shown by the 2020 census survey [141]. Consequently, there is a lack of understanding of the traditional knowledge of what truly constitutes "sustainability" and the indigenous strategies for achieving it. The current sustainable development paradigm is primarily focused on Western models; however, several studies have demonstrated that the traditional American indigenous worldview can help us rethink urban sustainability through an indigenous lens [5,10,37,112,137]. Traditional indigenous ecological knowledge and concepts of sacred as well as adaptive management [19,20] that have been lost at some point in time and occasionally reconstructed can help us to redefine urban sustainability [5,157]. Thus, many of the innovations supposedly needed to address modern urban challenges need not be out-of-the-box innovations at all, but rather reintroduce historic indigenous values and the thinking of the region. As many indigenous values were perfected over centuries to local conditions 'in situ' in the diverse landscapes of North America, these values and insights can be reconstituted so as to thrive and grow in new contexts.

In a move to improve this situation, the current US President Joe Biden in 2021 acknowledged this in a memo [118] where he described indigenous knowledge as "a body of observations, oral and written knowledge, practices, and beliefs that promote environmental sustainability and the responsible stewardship of natural resources through relationships between humans and environmental systems." This knowledge can be applied to various systems on multiple scales, including urban social systems [87,144], ecological systems [89,103,105,110,112], and technological systems [102].

Issues of scale

The issue of scale is becoming increasingly important in urban sustainability research. The scale can have horizontal (e.g., more single-family homes, more hybrid vehicles), vertical (e.g., transition from single-family to multifamily homes, transition from hybrid to electric), and hierarchical implications (e.g., government policies bringing public change). It can also be described as micro (e.g., individual or parcel), mezzo (e.g., neighborhood), or macro (e.g., city or state) [163]. The scale can also be global, regional, and local. At the global level, climate change is a major concern as it affects all regions of the world and requires collective action to mitigate and adapt to its impacts, which produces migration, food security, and natural disasters. Regional factors, such as proximity to natural resources and transportation networks, can affect resource availability and ease of implementing sustainable policies. At the local level, issues such as urban sprawl, land-use patterns, and access to public transportation can significantly impact sustainability.

The implications of sustainability differ depending on the scale used. This can be referred to as a contextual scale, which is a critical aspect to consider in sustainable development. The broader the scale, the more difficult it is to track aspects that may be relevant to individuals in the local communities [151]. Similarly, a finer-scale analysis can potentially conflict with a broad scale analysis by ignoring the success of widespread sustainability efforts, particularly among vulnerable communities. Goodling et al., [55], for example, demonstrated that perceptions of a progressive, sustainable city in Portland (Oregon) are limited to select areas of the city, leaving several other parts of the city in need of similar interventions. This occurs because viewing the sustainability assessment scale as either too broad or too narrow hinders progress in this area. Berardi [16] argued that improving the "sustainability assessment scale" would allow us to consider all domains of sustainability. Yigitcanlar et al., (2015) proposed a multiscalar approach (micro scale to macro scale) as a method that enables "benchmarking" micro-practices for macro lessons of sustainability. Additionally, policies and interventions tailored to the specific needs and contexts of local communities can help ensure that sustainability efforts are inclusive and equitable. Studies have shown that scale matters for all major dimensions of sustainability, including social [114], environmental [159], and technological [17] dimensions. It is essential to recognize and implement policies at different scales to achieve sustainable development.

Urban sustainability indicators

Research interest in social sustainability has varied over time (Fig. 2). Many authors have focused on broad indicators such as health, housing, income, and safety to describe the status of social sustainability in cities [164–166] (See Table 3). The indicators of social sustainability include culture and the economy. Not surprisingly, most social sustainability indicator studies address the issues of stakeholders while issues associated with dimension are least addressed. Many ecological sustainability indicators predate 1990, but only very recently have social indicators been assessed with equal interest. Ecological sustainability indicators can vary depending on scale and stakeholders; however, there is a consensus on ecological sustainability indicators that consider the quality of air or land in relation to air and land pollution, climate change, and conservation of natural resources. Studies on ecological sustainability indicators mostly address issues related to space and scale, given the nature and interest of measurement design and impact. Technological sustainability, unlike social and ecological sustainability, is a recently recognized domain. Studies on technological sustainability indicators all address issues related to space, while only one study addresses the issue of stakeholder engagement. Many technological sustainability indicators can be identified, but most of them have historically been associated with social or ecological indicators. For example, indicators such as transportation options and density of transit stops were considered social prior to the introduction of energy-efficient vehicles and real-time information on transit times. Similarly, innovations drive the progress of other indicators, such as high-speed Internet, green buildings, and smart homes [117]. Although these indicators are useful, there is less evidence that they work at multiple scales or that they are spatially inclusive and have a wide range of stakeholder support. We recommend that the use of indicators go through a local review involving stakeholders from multiple sectors (scale) and different neighborhoods (space). This process will allow the development of a shared understanding of what urban sustainability means and ensure that it is accepted by all stakeholders as meaningful.

Key recommendations and limitations

Based on the findings, we make the following recommendations. First, it was observed that the current implementation of urban sustainability initiatives lacks a holistic vision that considers all the necessary dimensions required to achieve success in this field. There has been a tendency to prioritize environmental sustainability over other dimensions, but there is growing recognition of the importance of social sustainability. However, the relationship between social sustainability and technological sustainability has not been fully explored, with the latter often considered a separate issue. Therefore, an integrated consideration of different dimensions, such as SETS, is important.

Second, key issues, such as space, scale, stakeholders, and dimensions, must be carefully considered while developing a comprehensive framework for preparing urban sustainability programs. These have implications for the equitable implementation of sustainability in cities. Careful consideration of these key issues will enable the development of comprehensive and inclusive frameworks that address the specific needs of each city. It is also important to recognize the diversity and complexity of urban environments and to tailor solutions to suit the unique challenges of each context. Furthermore, engaging with stakeholders and local communities is crucial for the successful implementation of sustainability initiatives, as they can provide valuable insights into the challenges and opportunities present in their communities. Consequently, we recommend that urban sustainability indicators

Table 3
SETS urban sustainability indicators (2010–2022) and major issue (s) for each indicator.

Social Indicators	Example	Sc	Sp	St	Di	References
Affordable housing	Density of affordable housing per sq.km	✓		✓		[164–166]
Access to open spaces	% Open space per neighborhood		✓	✓		[106,164]
Diversity	Population diversity per neighborhood			✓		[116,161]
Health	Density of hospitals per sq.km			✓	✓	[164,165]
Income	% Households below average income	✓	✓	✓	✓	[116,165]
Local or civic Identity / Sense of place	Density of culturally significant places			✓		[164–166]
Local economy	Gross Domestic Product (GDP)	✓	✓	✓		[164–166]
Safety	Number of crimes		✓	✓		[164,166]
Tourism	Number of tourists	✓	✓			[80,164]
Unemployment	% Population above 18 unemployed	✓		✓		[1]
Environmental Indicators		Sc	Sp	St	Di	
Air pollution	Pollution causing particles density	✓	✓			[116,165]
Climate change	Change in temperature patterns	✓			✓	[164,165]
Green Space	% Green space per neighborhood		✓	✓		[1,29,31,38,116,164,166]
Land use	Density of multi-use spaces	✓	✓			[107,164]
Natural environment	% Wetlands	✓	✓			[164]
Natural catastrophe exposure	Frequency/Magnitude of floods	✓	✓			[165,166]
Resource use	Water source and supply	✓	✓	✓		[1,109,164,166]
Waste production/management	Waste production by neighborhood		✓	✓		[107,164]
Water pollution	Water pollution per household	✓	✓	✓		[166]
Technological Indicators						
Bicycle infrastructure	Bicycle lanes per length of road		✓	✓	✓	[166]
Energy efficiency	Renewable energy adaptation per household	✓	✓			[1,166]
Electric vehicles	Density of electric vehicles per neighborhood	✓	✓		✓	[166]
Internet (high speed) availability	Internet speed by household		✓			[166,167]
Smart device penetration / Smart homes	Smart device by household	✓	✓			[166]
Transportation options	Transit density by neighborhood	✓	✓		✓	[164,166]

Sc = Scale | Space = Space | St = Stakeholder | Di = Dimension.

should undergo a local assessment that involves stakeholders from various sectors (scale) and diverse communities (space).

Although this study has provided valuable insights on issues related to urban sustainability, some limitations exist in our study. The study has mainly relied on secondary sources of information, such as peer-reviewed journal articles, to identify key issues and challenges in urban sustainability and has not actively engaged with urban practitioners to validate or supplement this information. Therefore, further research is needed to explore the practical relevance of these issues and determine the extent to which they can be transferred to different urban contexts. These limitations suggest potential avenues for future research.

Conclusions

In the United States, there are increasing calls to reflect on and remedy the ills that exist in society because of unfair historic policies and practices. Given the uncertainty associated with present and future climate change projections, it is imperative that methods for planning and implementing sustainability and adaptation measures become more common, equitable, and suited to local context. This review article discusses the dimensions of sustainability and the issues of space, scale, stakeholders, and dimensions that impact the successful implementation of sustainability in cities. The article emphasizes that separate interventions in different dimensions are less likely to result in overall sustainable evolution in cities. A more inclusive implementation would involve meaningful community engagement, co-production of knowledge, and equitable resource allocation while working to balance different dimensions of sustainability and increase people's understanding of sustainability. Research to improve knowledge should be more transparent. Sustainability implementation should not be unidimensional; instead, it should be in the interest of unifying society, environment, and technology. Hence, assessing the success or failure of sustainability implementation should be drawn from a comprehensive framework that involves society, environment, and technology. The structure of the assessment framework should include the languages and

categories relevant to sustainability across all stakeholders from multiple sectors and backgrounds in a city. Thus, the review suggests that failure to develop indicators based on critical urban sustainability issues should be viewed as a major limiting factor in the quest for a sustainable future. This review calls for more multiscale, spatially explicit, inclusive, and comprehensive measures for sustainability implementation to be developed for future research.

These findings have significant implications not only for the local US context but also for the international urban communities. Many cities worldwide face similar social, environmental, and technological challenges in implementing sustainable practices. Thus, our review can provide insights and guidance for policymakers and practitioners in these contexts as well. By focusing on different dimensions of sustainability, and considering issues such as space, scale, and stakeholders, this framework has potential transferability, which can contribute to the development of more sustainable and resilient cities globally.

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.

Data availability

No data was used for the research described in the article.

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