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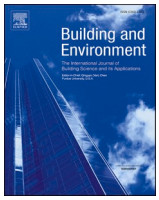

Equity in the built environment: A systematic review

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ABSTRACT

Equity in the built environment refers to the extent to which the built environment meets the needs of different groups through planning, design, construction, operation, management, and regulation. Though much studied in recent years, some needs and groups have received a greater research focus than others, and significant inequities continue to exist. Following PRISMA guidelines, we systematically reviewed the distributional and recognitional aspects of inequities experienced by vulnerable groups regarding their needs while using/occupying different types of built environments. We find that more studies focus on inequities regarding residential buildings, transportation facilities, and public open spaces, whereas comparatively few studies examine water and energy infrastructure, commercial buildings, educational buildings, and healthcare facilities. More studies focus on well-being, mobility, and access needs than shelter and safety needs. Inequities experienced by minorities, people with low socioeconomic status, people with health concerns, and vulnerable age groups receive more attention than the inequities experienced by people with gender/sexual-orientation vulnerability or displaced groups. The literature exhibits a relatively narrow focus on some subgroups, such as refugees, people experiencing homelessness, people with cognitive differences, people with visual or hearing impairments, children, and women. We argue that these findings demarcate high-impact future research directions to address vulnerable groups' needs worldwide and suggest measures to alleviate inequities in the built environment.

1. Introduction

The *built environment* includes human-made buildings and infrastructure that provide physical settings for human activities. It plays an essential role in addressing the basic needs of society, such as having places to live, work, learn, travel, and entertain. The built environment can contribute to a more just society by accommodating the needs of different individuals and groups. However, longstanding approaches towards planning and developing the built environment have often neglected the needs of many groups. For instance, one-third of urban dwellers in the developing world (around 863 million people) live in slums and face major challenges associated with poverty, substandard housing and services, under- or informal employment, violence, and more [1]. Even in more-developed countries, built environments negatively affect the physical, mental, and emotional health and well-being of individuals experiencing homelessness [2], minorities, people with low socioeconomic status (SES) [3], and people with disabilities [4]. Over the life cycle of a built environment project, equity can be advanced or impeded in a variety of ways, including during commissioning, planning, design, construction, material procurement, and daily usage [5]. Even if the undesirable impacts of the built environment on communities are unintended consequences, these inequities cannot be disregarded.

The design, construction, or operation of built environments to satisfy the needs of a specific group might not fulfill the needs of other groups, and the differences in human needs and behaviors in built environments might be too wide to be considered altogether. These differences can be even contradictory, such that satisfactory features for some groups might harm others. In indoor environments, older occupants prefer rather higher indoor temperatures, while younger occupants prefer cooler indoor environments [6]. Considering varying occupant/users' needs becomes even more problematic when accounting for limited resources in the life cycle of the built environment (e.g., time and budget) [7]. Therefore, designing for the broadest possible users of the built environment while considering the differences between several groups is a challenging task. This requires noticing that

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some groups might benefit more than others from the built environmental features, and relative differences generally benefit the less able or most disadvantaged groups (equity-based approach) [7].

It is also important to acknowledge the potential issues embedded in specific disciplines and/or brought on by the field itself. For instance, in relation to integrating equity concerns with engineering practices, there are challenges such as (1) the tendency of engineers to separate between technical and social concerns, (2) engineering beliefs that success is derived from individual efforts, disconnected from systems of privilege and disadvantage, (3) beliefs that engineering can and should be detached from considerations of equity, power, and social justice [8]. "Social Justice in Engineering" recognizes and considers the effects of engineering decisions on a broad range of communities [9]. In fields such as urban planning, discussions of equity in the built environment include a focus on just processes. Being just, ultimately, is the outcome of successfully using design tools, applied in concert with those who inhabit the built environment. This helps address inequities and develop spaces and places that welcome and support everyone's quality of life [39].

Building upon this background in engineering and planning, we define *equity in the built environment* as the extent to which the built environment meets the needs of different groups through planning, design, construction, operation, management, and regulation. In this context, distributional equity includes the equitable functionality of the built environment and infrastructure in response to human needs, abilities, and capabilities in the built environment [10]. In the same context, recognitional equity encompasses: (1) acknowledging different intersecting identities (e.g., race, gender, class, and age) within societies, (2) recognizing that these identities are shaped by historical injustices and can affect the vulnerability of humans in the built environment, their experience and ability to access, occupy, and function in the built environment, and their capacity to participate in decision-making, and (3) promoting respect for different groups [10]. Finally, procedural equity involves equitable participation in decision-making and inequity-resolving processes. This includes public participation in the development of the policies, efforts to increase ongoing public participation in the governance of the built environment, and solutions to improve the experience of marginalized groups within the built environment [10]. Based on the provided definition, we propose a ***built environment, (vulnerable) groups, and needs (BGN) model*** to clarify the inequities experienced by different groups within built environments (Fig. 1).

Equity in the built environment first requires the identification of distributional and recognitional aspects. Second, it needs resolution or procedures for addressing these inequities through the participation of different groups. This includes finding solutions to identified issues, given limited resources and conflicting needs among individuals and groups. Alleviating inequities in the built environments requires collective efforts globally; however, the varying vulnerable groups and inequity issues, as well as different characteristics of geopolitical and socioeconomic environments across countries, make it hard to develop a universal research effort to address the inequities worldwide. Thus, efforts to address these problems can be followed on a national scale first and then extend the lessons learned to larger scales worldwide. Given that data and research availability around inequities in the United States (U.S.) enables developing procedures for identifying inequities and resolving them, which can be further modified for other countries based on their specific characteristics of geopolitical and socioeconomic environments.

Thus, this review study aims to identify the foundational research pillars of equity in the built environment, focusing on the first phase of identifying inequity issues and identifying key research gaps within the U.S. context. It identifies the types of built environments where inequities exist, the vulnerable groups experiencing these inequities, and the key needs of these groups related to the built environment (i.e., the BGN model). To do so, it synthesizes the literature to identify distributional equity and recognitional equity patterns across different types of built environments to answer the following research question: *What are the neglected (or less considered) needs of vulnerable groups in different types of built environments in the U.S.?*

2. Background

Equity, equality, and justice have been defined in several ways. Table 1 provides brief summaries of some of the discussed definitions for related key terms.

Definitions of equity and justice have evolved over time. Equity exists in two primary dimensions: horizontal equity (equality) and vertical equity. Horizontal equity involves the equal distribution of resources, regardless of people's varying needs, abilities, or capabilities [23,24]. However, vertical equity correlates with fairness [25], and resources are distributed according to the people's needs, thus, representing a more justice-oriented focus [23]. Justice itself has been explored through different theories such as utilitarianism, libertarianism, intuitionism, Rawls' egalitarianism, and Capability Approaches (CAs) [26], among which Rawls' egalitarianism has been implemented more in cross-disciplinary studies. Political theorists traditionally understood justice in relation to the distribution of goods and freedoms. However, distribution is not the only cause of inequities, and therefore, redistribution cannot be chosen as the only solution to alleviate these inequities [27]. For instance, disparities in access to bike lanes could arise because of inadequate incorporation of equity considerations into planning goals, inadequate representation or involvement of disadvantaged groups in decision-making, or inactive demand from these groups regarding cycling infrastructure [28].

In recent decades, different methods, concepts, and standards have sought to alleviate inequities in the built environment. For example, approaches such as Universal Design [29] and Inclusive Design [30],

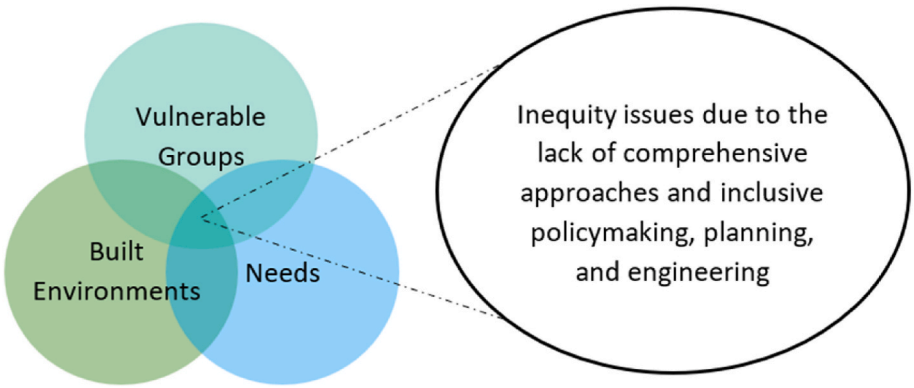

Fig. 1. BGN model Venn diagram.

Table 1
Definitions of key terms.

Key term	Definition
Horizontal Equity (Equality)	Each individual or group in society is able to meet their needs since they have access to the same amount of resources separately [11].
Vertical Equity	Providing each individual or group in society with a varying amount of resources that is proportional to the level of their needs and vulnerabilities [11].
Distributional Equity	Equitable access to goods and infrastructure, environmental amenities, services, and economic opportunities [10].
Recognitional Equity	Equal acknowledgment and respect of different identities and associated social status [10,12].
Procedural Equity	Equitable spaces of engagement that determine who is involved with shaping the social, built, and ecological environment [13,14].
Justice (Rawls' Conceptualization)	Framed around concepts of egalitarianism and equity of both freedoms and materials, namely, that the most disadvantaged people in a society ought to receive the most benefits to figuratively "raise the floor" and eliminate their comparative disadvantage [15,16].
Social Equity/Justice	The extent to which resources, opportunities, benefits, and burdens are allocated fairly across society [17].
Environmental Justice	The fair treatment and meaningful involvement of all people, regardless of race, color, nationality, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies [18].
Social Vulnerability	The set of characteristics of an individual or a group that influences their capacity to anticipate, cope with, resist, and recover from the impact of a hazard [19].
Just City	A city where public investment and regulation would produce equitable outcomes rather than support those already well off [20,21].
Universal Design/Inclusive Design	Approaches to design environments useable by all people to the maximum of their abilities without requiring specialized adaptation or design [22].

and concepts such as Social Vulnerability [31], Environmental Justice [32,33], and the Just City [20,21] aim to identify and attenuate built environment inequities. In addition, multiple standards have been established to address inequities directly and indirectly. For instance, the Americans with Disability Act (ADA) [34] tries to minimize access-related inequities in the built environment. Additionally, adherence to guidelines set forth by the Federal Emergency Management Agency (FEMA) [35], sustainability metrics such as Leadership in Energy and Environmental Design (LEED) [36], and health standards such as WELL [37] work to address resilience, environmental, and health-related equity goals related to the built environment.

These approaches and standards, though noteworthy, may not fully address inequities in different types of built environments or across various life cycle phases. For instance, *environmental justice* has been developed to tackle environmental disparities and inequities and tends to focus more on natural environments, resources, and supporting infrastructure (e.g., water and energy). *Social vulnerability* within the built environment context is mainly discussed through disaster-oriented perspectives; however, the operation of built environments is not limited to disaster scenarios and includes regular conditions as well. Additionally, the *Just City* concept tends to focus more on inequities within urban areas, while rural habitats are experiencing inequities as well. From another perspective, building standards (e.g., ADA) mainly provide general requirements and may lack adequate information about how different types of built environments address the diversity of needs in society [38]. Regarding *universal design* and *inclusive design,* the recent notion of building inclusively aims to embrace key sociological and behavioral aspects, such as physical, sensory, and cognitive needs, alongside physical accessibility [39]. However, these approaches are mainly shaped around the design phase, even though inequities regarding the built environment might be caused by deficiencies in other phases such as planning, construction, operation, and management. Additionally, discussions on approaches such as universal design tend to be less focused on how to translate its principles into practices. This lack of focus leads to restrictions in recognizing and responding to patterns and processes of social and cultural diversity [40].

3. Methodology

Procedures for this study followed the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 Statement [41] - the most cited guideline for systematic reviews-to search for, appraise, synthesize research outcomes, and collect knowledge on the intended topic area.

Previous review studies about inequity problems in the built environment have either focused on specific vulnerable groups, types of the built environment, or needs [42–49]. Thus, by integrating keywords used in these studies, a comprehensive combination of keywords was created to establish a holistic understanding of the inequities related to the built environment. Then, the draft list of keywords was iteratively assessed during team meetings while seeking guidance from scholars in engineering, architecture, social studies, and behavioral sciences, all affiliated with the University of Southern California. The Web of Science was used as the search database since it is an extensive search system consisting of multiple databases and includes high-impact studies. In addition, Web of Science reliably searches across publishers and is not biased toward journals published by any company [43]. Three bibliometric categories were considered for the preliminary screening of relevant papers: title, abstract, and keywords. Four lines of search strings were formed to capture the relevant research articles. The lines and search operators were combined as follows: $(AB = L_1\ OR\ TI = L_1\ OR\ AK = L_1)\ AND\ (AB = L_2\ OR\ TI = L_2\ OR\ AK = L_2)\ AND\ (AB = L_3\ OR\ TI = L_3\ OR\ AK = L_3)\ AND\ (AB = L_4\ OR\ TI = L_4\ OR\ AK = L_4)$, where AB, TI, and AK stand for abstract, title, and author keywords, respectively. The selected keywords for L_1, L_2, and L_3 aimed to cover vulnerable groups, built environments, and key needs, respectively. In addition, the keywords for L_4 were chosen to limit the search within the scope of pertinent concepts. Table 2 summarizes the list of keywords.

After removing duplicates, 6731 articles were retrieved. No time restriction was applied. The articles were screened based on their titles and abstracts, and the papers were considered if they were relevant to the topic of study. The eligibility of some articles based on their abstracts and titles was unclear; therefore, in these cases, the articles' full texts were screened. The screening and selection of articles were duplicated by coauthors, and disagreements were resolved through discussion. After this phase, 295 articles were included. Only the studies with a concurrent emphasis on the built environment, vulnerable groups experiencing inequalities, and the types of needs were considered. Any publication that lacked one of these three dimensions was excluded. Additionally, only empirical studies were included in the final dataset; thus, review studies, theoretical studies, and position papers were excluded. Moreover, non-English studies or those focused on inequity issues outside of the U.S. were removed. In addition, conceptual descriptive studies that did not specify a methodological approach were not included in the final dataset of articles. The references of included articles were also searched to identify additional studies using the 'forward and backward' citation tracking method (based on the article title). The final list consisted of 232 relevant papers. The PRISMA flow diagram, which the research team used to identify the final set of papers, is shown in Fig. 2.

As discussed before, the objectives of this study encompass four main dimensions, namely built environments, vulnerable groups, needs, and issues. Accordingly, the subdivisions that belong to each dimension were determined, as explained below in Fig. 3.

3.1. Built environments

Several references were analyzed for a comprehensive list of

Table 2
Categorized keywords used for search strings.

Built Environments (L_1)	Building*, Built-environment*, Infrastructure*, Neighborhood, Cities/City	Vulnerable Groups (L_2)	Minorit*, Marginalized, Underprivileg*, Disabled/Disabilit*, Neuro-diver*, With-special-needs, Vulnerab*
Needs (L_3)	Safety, Security, Comfort, Satisfaction, Performance, Well-being, Wellness, Access*, Learning, Health*, Accommodat*, Shelter, Hygiene, Mobility, Livability/Liveability, Housing, Quality, Walkability, Residenc*, Occupatio*	Approaches and Concepts (L_4)	Equit*/Inequit*, Justice*/Injustic*, Equalit*/Inequalit*, Inclusi*, Diversity, Design-for-all, Universal-design, Human-centered, Social-sustainability

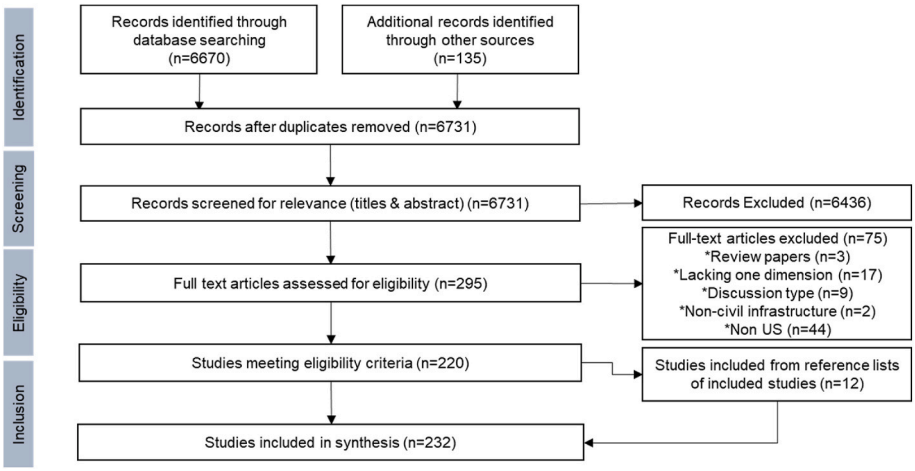

Fig. 2. PRISMA – based flow diagram describes the steps taken for the systematic review.

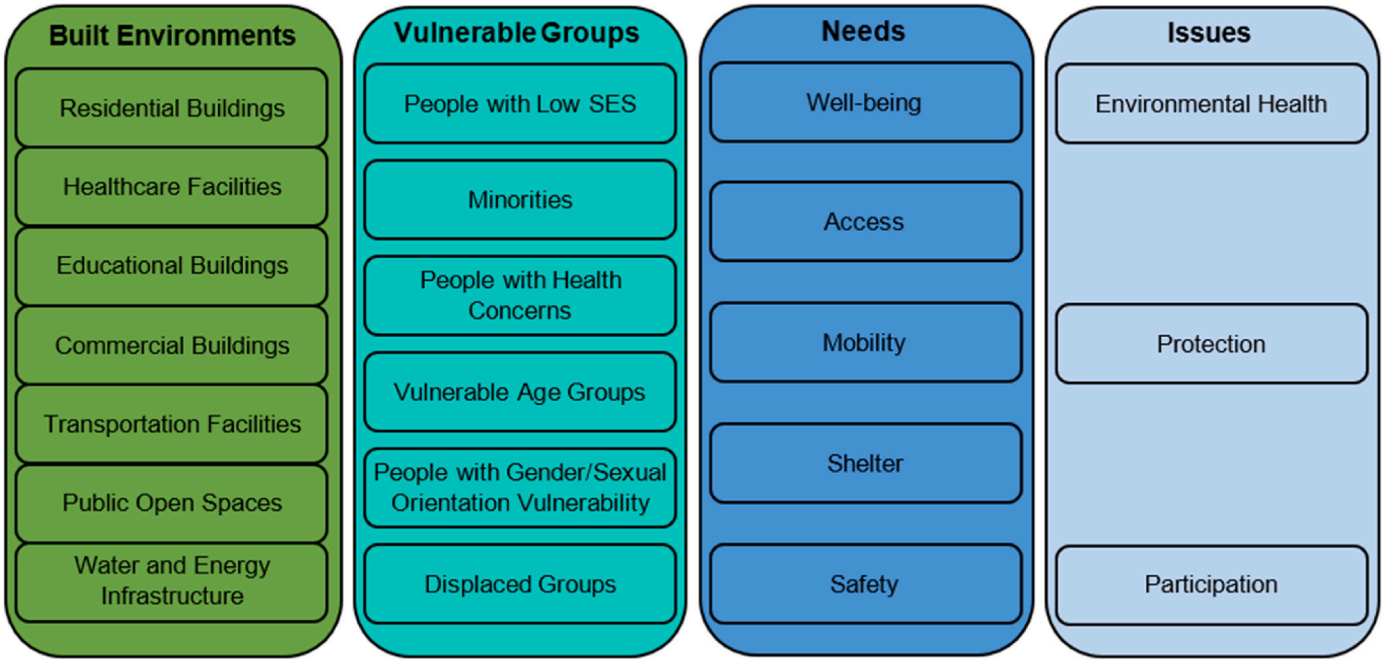

Fig. 3. Subdivisions within the four dimensions of the review study.

different types of built environments. After reviewing the United Nations (UN) Habitat urban planning toolbox [50], the United Nations High Commissioner for Refugees settlement profiling document [51], land-use classification schemes [52], elements of urban form [53], and the U.S. census statistics [54], built environments were categorized into seven types including: (1) Residential buildings (e.g., single family housing, apartment buildings); (2) Healthcare facilities (e.g., health care, institutional, and social protection buildings); (3) Educational buildings (e.g., schools, cultural centers such as libraries); (4) Commercial buildings (e.g., offices, hotels, motels, stores, restaurants, shopping centers, public garages, drug stores, banking and financial services, recreational and entertainment centers, manufacturing and ndustrial facilities); (5) Transportation facilities (including routes e.g., streets, bike paths, sidewalks and terminals e.g., bus stops, metro stations, airports) (6) Public open spaces (e.g., parks, playgrounds); and (7) Water and energy infrastructure (e.g. fresh water distribution network,

power grid).

3.2. Vulnerable groups

Vulnerable groups were identified using references that focused on human rights issues related to physical spaces. After reviewing the UN-Habitat urban planning toolbox [50], PROGRESS CANDALS[1] health equity factors of World Health Organization (WHO) [55], PROGRESS-Plus[2] health equity factors [56,57], human rights protections for vulnerable and disadvantaged groups research [58], UN-Habitat rights to adequate housing [59], and UN economic and social council's general comment no. 20 [60], six vulnerable groups were identified, including: (1) People with low SES (such as people with low income, unemployed groups, and people who reside in underprivileged areas such as slum dwellers, people living in informal settlements); (2) Minorities (such as racial/ethnic minorities and indigenous groups); (3) People with health concerns (such as people with mobility disabilities, people with cognitive differences, people with visual or hearing impairments, and people with any other health problems); (4) Vulnerable age groups (such as infants, children, young, and elderly groups); (5) People with gender/-sexual orientation vulnerability (such as men, women, LGBTQIA); and (6) Displaced groups (such as migrants, refugees, stateless and internally displaced persons, and people who experience homelessness). When necessary, certain vulnerable groups were analyzed according to their associated subgroups. For instance, among vulnerable age groups, there are noticeable differences in the effects of built environments on children and the elderly. Therefore, these two subgroups were considered separately in the cross-tabular analysis and discussion. Moreover, intersecting vulnerabilities (e.g., the coexistence of reduced mobility and being a child) worsen the experienced inequities in the built environment. However, in this paper, these intersections were not explored and discussed jointly.

3.3. Needs

Using the World Bank document on gender-inclusive cities [61] and the UN-Habitat handbook about slum upgrading [62], human needs related to the built environment were identified and categorized into six types: (1) Well-being, includes physical, mental, and social health (i.e., cardiometabolic biomarkers, anxiety state, community engagement); (2) Access (i.e., using services and spaces in the built environment, free from barriers and constraints [61]); (3) Mobility (i.e., moving around the built environment easily, safely, and affordably [61]) (4) Shelter (i.e., the fundamental requirement for a safe and secure place to live or take refuge); [63] (5) Safety (i.e., protection, security, and freedom from harm); [64]. It is important to acknowledge that not all needs or vulnerabilities are applicable to every type of built environment, and as a result, the figures presented in the results and discussion section encompass these categories accordingly.

3.4. Issues

To have a detailed view of the underlying factors of inequities in the built environment, the different types of issues that cause inequities in built environments were recorded alongside the types of built environments. Issues can be clustered into three main types, including environmental health issues, protection issues, and participation issues [65]. Within *environmental health issues*, air pollution, energy poverty, insufficient green space, lack of proper water resources, noise pollution, and toxic waste and materials were included. In addition, *protection issues* include improper housing location and quality, unaffordable housing, unsafe roads, walking zones or surrounding environment, and violence hotspots. Lastly, exclusion in planning and engineering practices, lack of walkable areas, physical inaccessibility, uneven distribution of amenities and services, and weak connectivity were considered *participation issues* related to built environments.

A standardized form was developed to extract the necessary information from each paper based on the BGN model. These included fields are listed in the Appendix. Finally, the data were synthesized by exploring trends in previously listed dimensions, year of publication, and geographical region of the study. Many of these areas of interest were studied within cross-tabulated analysis (e.g., frequency of key needs of various groups in different built environments). To have a comparative understanding of the studied areas and potential research gaps, the number of publications was considered the main criterion of research attention. However, the relation of research attention to actual real-life problems was not explored in this study.

4. Results and discussion

To illustrate the most explored research problems, a word cloud was constructed from titles, abstracts, and keywords of all the included papers in the study. A word cloud creates a visual depiction of words based on their frequency [66]. With this approach, the size of a word in the generated image corresponds to how frequently the term appears in the analyzed text, thereby emphasizing its prominence. The words associated with equity in the built environment and their corresponding frequency are shown in Fig. 4. The most common words reported were health, environmental, neighborhoods, access, urban, and communities. This word cloud validates that the topic of inequity in the built environment encompasses several domains.

4.1. Geographical and temporal highlights

The geographical distribution of studies is projected in Fig. 5. The

Fig. 4. Word cloud from the most common words in studies related to equity in the built environment.

[1] Place of residence, race or ethnicity, occupation, gender and sex, religion, education, socioeconomic status, social capital or resources, citizenship, ability, neurotypicality or neurodiversity, disability, age, literacy and/or fluency in a universal language of aviation, and size, body mass index (BMI) or body habitus.

[2] Place of residence, race/ethnicity/culture/language, occupation, gender/sex, religion, education, socioeconomic status, and social capital plus personal characteristics that attract discrimination (e.g., age, disability), features of relationships (e.g., smoking parents, excluded from school), and time-dependent relationships (e.g., leaving the hospital, respite care, other instances when a person may be temporarily at a disadvantage).

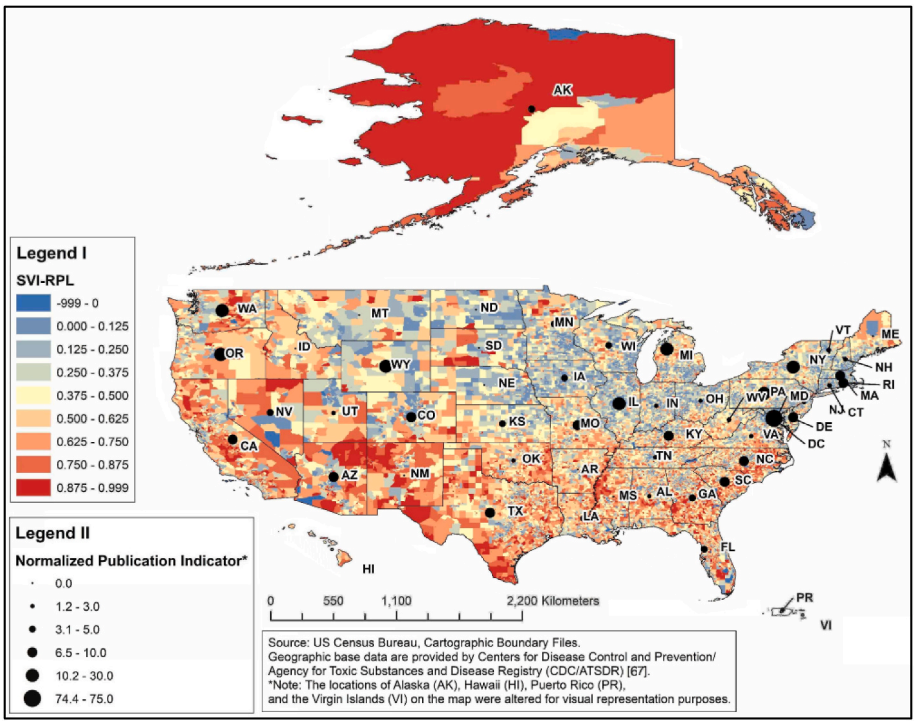

Fig. 5. Geographical distribution of SVI and studies focusing on inequities in the built environment. *Indicator = 1.0E07*(number of publications)/(state/district population).

depicted results were based on the location of studied inequity issues (not necessarily the location of institutions affiliated with the publications). Washington DC, Illinois (IL), Pennsylvania (PA), Michigan (MI), Washington (WA), Wyoming (WY), Oregon (OR), and New York (NY) emerged as the most prominent states for research on inequities in built environments, evident by their population and their highest number of publications, while several states, such as Arizona (AZ), California (CA), Texas (TX), and North Carolina (NC) exhibit a moderate level of research focus, indicating notable research presence. Conversely, states like Alaska (AK), South Dakota (SD), Idaho (ID), and others show lower publication numbers, suggesting comparatively less research activity regarding inequity issues in the built environment. The results show vast disparities in the geographical distribution of studies about inequities in built environments across the U.S.

Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR) developed the Social Vulnerability Index (SVI) as a tool to assess and measure the social vulnerability of communities in the U.S. Additionally, and to gain better insights, Fig. 5 presents the distribution of social vulnerability across U. S. This index takes into account various factors such as socioeconomic status, household composition, minority status and language, housing type and transportation, and disability status. These factors help identify communities that may be more vulnerable or less resilient in the face of public health emergencies or disasters. The Ranking Percentile (RPL) in the SVI indicates the relative position of a specific geographic area or community compared to others. It represents the percentile rank of a particular area's social vulnerability when compared to all other areas included in the SVI dataset. For example, if an area has an RPL of 80, it means that it ranks higher than 80% of the other areas in terms of social vulnerability [67]. Mapping the distribution of included studies on SVI distribution illustrates that in certain areas, less focus has been given to inequities experienced by vulnerable groups within the built environmental context. More specifically, central CA, south and southwest TX, northeast AZ, New Mexico (NM), SD, southern Colorado (CO), ID, northern Nevada (NV), western Mississippi (MS), eastern Oklahoma (OK), AK, and the Virgin Islands (VI) need more research attention.

As depicted in Fig. 6, the focus on inequity issues in the built environment has rapidly grown over the years. Out of the 232 studies under review, only 1 (<1%) was published before 2001, 29 (13%) were published between 2001 and 2010, 92 (40%) were published between 2011 and 2020, and the remaining 110 studies were published after 2020. This growing trend is more noteworthy than the overall increasing trend of total publications in the U.S. (Fig. 6 [68], which illustrates that inequity in the built environment is getting relatively more attention.

The increasing focus on equity in the built environment has been driven by several factors alongside the general growth trend in global research. First, while still 37.9 million U.S. people live in poverty [69], social awareness about these inequities has increased over recent years. For instance, after the killing of George Floyd and in response to the civil unrest of the summer of 2020, design organizations made a list of statements to address systemic racial injustice in the U.S [70]. Therefore, U.S. communities have become more aware of the existing inequities among various vulnerable groups and have asked for the resolution of these inequities. In addition, more funding resources have been allocated, and more cross-disciplinary research collaboration has been fostered recently to facilitate addressing the different aspects of inequity in the built environment. The funding details of included studies point out that funding agencies (e.g., US National Institutes of Health (NIH), National Science Foundation (NSF), and National Institute on Minority Health Disparities (NIMHD)) have granted several relevant projects in recent years. This variety of funding sources points to the trend at which different disciplines address the inequities related to the built environment. Finally, extreme events such as disasters, wars, and pandemics are becoming more frequent and intense, which has further exacerbated pre-existing inequities, including those associated with the built environment, and thus, have necessitated more research in this regard. Initiation of programs such as Justice40 is expected to help alleviate inequities in several areas, including climate change, clean energy and energy efficiency, clean transit, affordable and sustainable housing, training and workforce development, remediation and reduction of legacy pollution, and the development of critical clean water and wastewater infrastructure [71].

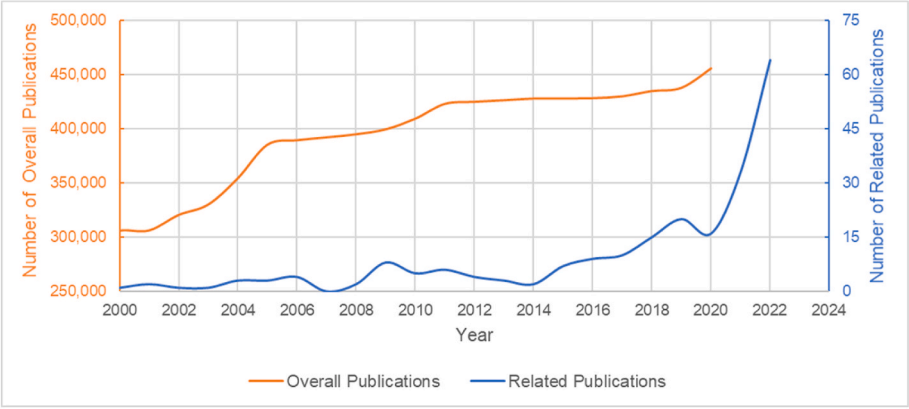

Fig. 6. Temporal distribution of studies on inequity issues in the built environment within the U.S. context and temporal distribution of all publications in the U.S. [68].

4.2. Issues of inequity in built environments

The representative data of the different issues of inequities (i.e., environmental health, participation, and protection issues) in the U.S. built environment is depicted in Fig. 7. According to the collected data, environmental health and participation issues received more research interest than protection issues. In terms of environmental health issues, air pollution, insufficient green space, and toxic waste and materials were studied more than the other constraint types. Publications focusing on participation issues within the U.S. context were mainly oriented toward the uneven distribution of amenities and services, physical inaccessibility, lack of walkable areas, and exclusive engineering and planning practices. However, the effect of weak connectivity on inequities in U.S. built environments was relatively less explored. Considering protection issues, more than half of the studies focused on inequities caused by improper housing location and quality. However, inequities due to unsafe roads, walking zones, and surrounding environments, as well as unaffordable housing and violence hotspots, were explored in relatively fewer studies.

Equity goals in built environments can be achieved by implementing efficient methods in dealing with inequity issues. Locating public amenities and services within reachable distance for all groups could increase social participation [72]. In addition, reducing physical barriers (e.g., removing barriers in favor of pedestrians with disabilities) enhances the participation of built environment users [4]. Improving the walkability of outdoor areas [73] and connectivity between neighborhoods through public transport [74] could also motivate different vulnerable groups to engage more in social life. Moreover, integrating education, research, planning, design, construction, and operation practices with inclusive viewpoints could help extend equity objectives among contributing stakeholders (e.g., designers, engineers, urban planners, social scientists, and more) [75]. Regarding environmental health issues, reducing air pollutant emissions [76], providing an active lifestyle by accessible and sufficient green infrastructure [77], monitoring toxic materials around occupancy areas [78], and proper water resources to improve hygiene [3] could mitigate many health-related risks and inequities among various vulnerable groups. However, as highlighted in Ref. [163], inequities in the built environment can also cause health concerns among certain populations such as greater air pollution, which is associated with higher asthma in neighborhoods with more Black residents. In addition, supplying safe and clean energy to those without access to energy resources for cooking, heating, and cooling could reduce disparities [79,80]. Affordable and standard housing plays a significant role in feeling protected against environmental conditions and hazards [81]. Knowing that the U.S. had a shortage of 7 million affordable homes for low-income renters [82], more efforts should be made to ensure the affordability of good quality housing. Additionally, increasing the safety of neighborhoods through improvements in public spaces' cleanness, lighting, and visibility conditions decreases violence and deters potential offenders [83].

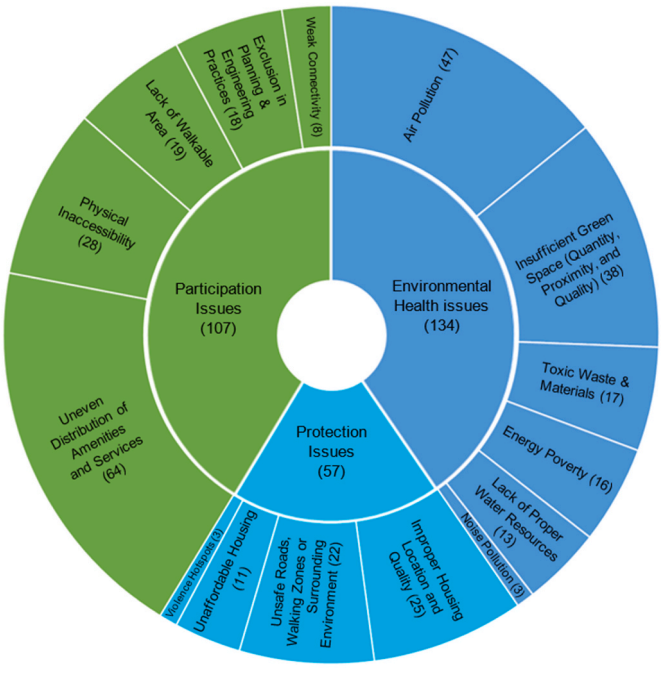

Fig. 7. Different types of inequity issues in the built environment.

4.3. Built environments, vulnerable groups, and needs

According to the BGN model, separate analyses were done to examine how frequently different aspects of equity in the built environment were studied. Fig. 8 presents the distribution of studies based on the type of built environments under study, vulnerable groups, and needs. Transportation facilities, residential buildings, and public open spaces were each studied in a notable portion of the included publications. However, water and energy infrastructure, commercial buildings, educational buildings, and healthcare facilities received relatively less attention. Results regarding the vulnerable groups showed that minorities and people with low SES were studied in the majority of included publications. On the other hand, a minor portion of studies focused on inequities experienced by displaced groups and people with gender/sexual orientation vulnerability. The results showed that inequities related to well-being, mobility, and access received the bulk of the

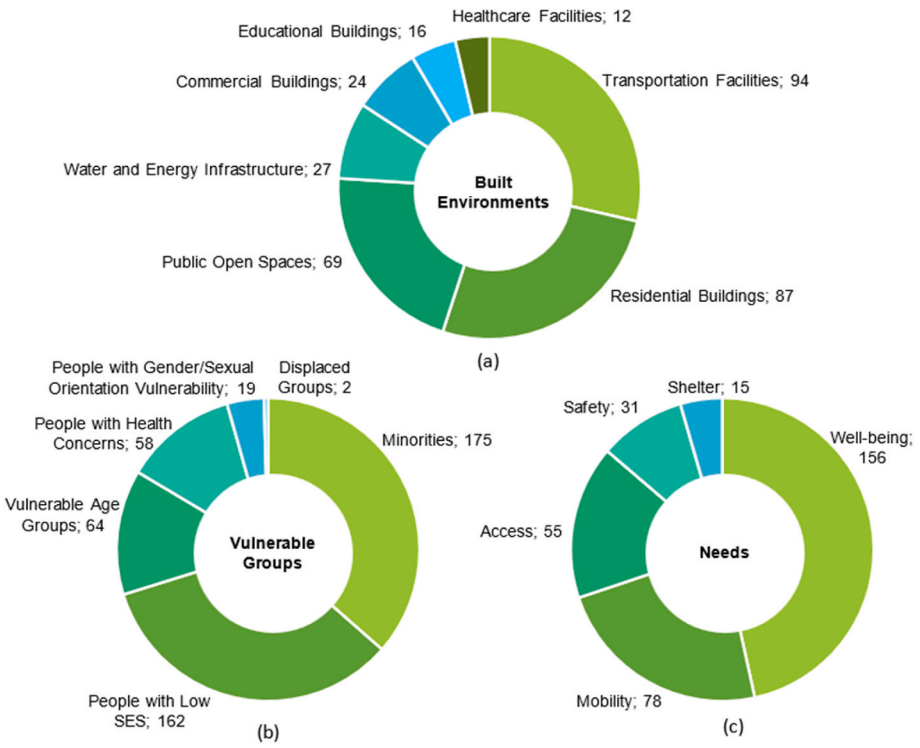

Fig. 8. Distribution of studies based on (a) types of built environments, (b) vulnerable groups, and (c) needs.

research interest, while the remaining needs (i.e., safety, shelter) were less explored. It is worth mentioning that some publications focused on more than one category within each dimension. To that end, the cumulative number of studies within each dimension is more than the total number of studies under review, which is 232.

There are several interconnections between the four dimensions of the BGN model. Cross-tabular analysis of these interconnections could help find more robust answers to the research questions and uncover significant research gaps while defining new research directions.

4.3.1. *Transportation facilities*

According to the results presented in Fig. 9, the 94 papers related to inequities regarding transportation facilities mainly focused on mobility, access, and well-being needs. A total of 72 studies focused on mobility needs, majorly examining the effect of uneven distribution of transportation facilities and the weak connectivity between the components of transportation networks on minorities, people with low SES,

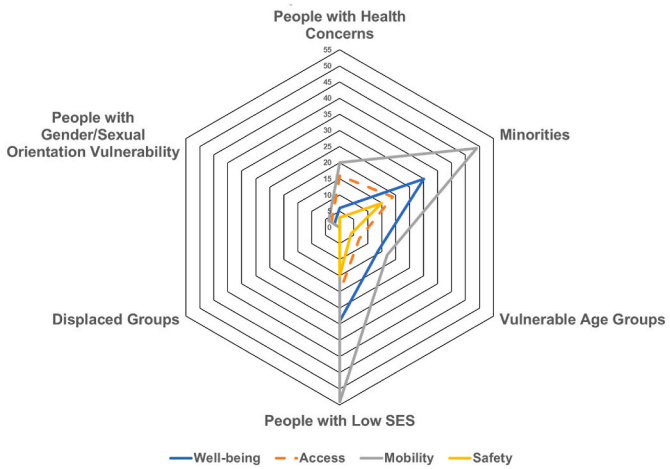

Fig. 9. Vulnerable groups and their needs related to transportation facilities.

people with health concerns, and vulnerable age groups [72,74]. There were limited or no studies regarding the mobility needs of people with gender/sexual orientation vulnerability, while there are pieces of inequity evidence in this regard. For instance, female elderly with a medical condition(s) and with low-income status suffered the most after the cessation of driving [85]. It is worth noting that transportation choices also have a substantial impact on various determinants of health and overall well-being, encompassing stress levels, self-efficacy, and perceptions of social isolation and connectedness. Notably, individuals with disabilities or elderly individuals may face heightened challenges in fulfilling transportation-related social obligations, consequently experiencing more pronounced health consequences [86].

Regarding the mobility needs of people with health concerns within the context of transportation facilities, some vulnerable groups, such as people with cognitive differences and people with visual or hearing impairments, have received less attention. However, recent research projects have tried to take advantage of technological advancements in facilitating mobility for these groups through the development of autonomous vehicles [87]. Also, some studies focused on assessing the effects of sidewalks' physical characteristics (e.g., slope surface, sidewalk width) on the mobility needs of visually impaired groups [88].

Regarding well-being needs related to transportation facilities, most of the 40 relevant papers mainly studied these needs among minorities, people with low SES, and vulnerable age groups. Uneven distribution of transportation facilities [89], lack of walkable areas [73], and inequitable distribution of environmental health hazards (such as air pollution) [90] were among the issues that limit the convenient participation of vulnerable groups and threaten their health and well-being.

Considering access needs with regard to transportation facilities, the focus of 31 studies was mainly on how physical inaccessibility in transportation facilities [4], exclusion in planning, design, and construction of these facilities [91], and uneven distribution of them [28] hinder the participation of minorities, people with low SES, and people with health concerns, especially people with reduced mobility. However, there was a limited number of publications about the access needs of vulnerable age groups and displaced groups. The relationship

between transportation facilities and the access needs of people with mobility disabilities has received researchers' attention for decades [92]. Given this history of research and the noteworthy population of people with mobility impairments (e.g., 12.1% in the U.S. [93]), a broad focus on this area is understandable. This continued focus has led to guidelines and standards to ensure accessibility requirements, such as ADA, in the U.S [94]. In addition, taking advantage of community engagement [95] and assistive technologies [96] helps extend accessibility compliances about transportation facilities and other types of built environments [97].

Regarding safety needs pertaining to transportation facilities, the included 18 papers focused on minorities, people with low SES, vulnerable age groups, and people with health concerns through studying unsafe roads, walking zones, and violence hotspots. For instance, Rebentisch et al. explored safety inequities regarding pedestrian and cyclist crashes [98]. Safety-oriented inequities can be tackled through adaptations in the physical environment of transportation facilities. For instance, improved crossings, lighting, and separation from traffic contribute to pedestrian safety [99]. It should also be noted that safety in transportation facilities can lead to a healthy lifestyle. For instance, safe road crossing points and traffic calming are positively associated with active transportation (e.g., walking, cycling) among children [99]. People with gender/sexual orientation vulnerability could also experience inequities in transportation facilities. For instance, sexual victimization is associated with the cleanliness of transportation facilities [100]. However, there was less focus on the safety needs of people with gender/sexual orientation vulnerability regarding transportation facilities, and thus, more research might be needed in this regard. Regarding safety in extreme events, the lack of suitable transport is a key factor in persons with disabilities' reluctance to evacuate before disasters such as hurricanes, which indeed is a barrier to post-disaster safety and recovery [101]. Individuals with disabilities also have more problems with transportation between shelters and disaster assistance centers, which can hinder their safety [102]. These collective findings presented here are in line with previous studies in other domains such as human ecology and sociology. For example, it was found that individuals from minority and poor neighborhoods travel to neighborhoods that have greater air pollution levels than the individuals from White and nonpoor neighborhoods [84], highlighting environmental inequalities. To mitigate these inequities experienced by various groups, increasing the redundancy of transportation networks can enhance the availability of alternative routes, circumventing damaged nodes and links [103].

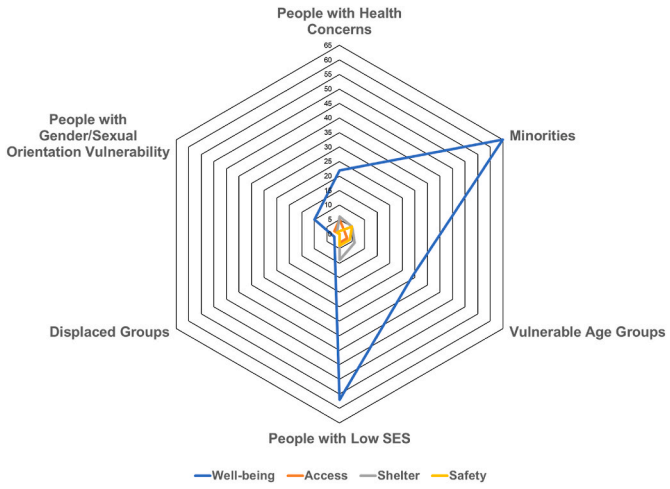

Fig. 10. Vulnerable groups and their needs related to residential buildings.

4.3.2. Residential buildings

Fig. 10 illustrates the distribution of 87 studies about residential buildings in terms of vulnerable groups and their needs. Most of these studies focused on the well-being needs of various vulnerable groups, particularly minorities, people with low SES, and vulnerable age groups. Well-being-related needs were mainly affected negatively by air pollution as well as improper housing location and quality. There were fewer studies on displaced groups' (e.g., refugees, homeless people) well-being needs, while there are various pieces of evidence about the poor conditions of homeless shelter camps that affect the health and well-being of people experiencing homelessness [104]. Given that the rate of displacement due to homelessness is still high in the U.S. [105], ascertaining the bare minimum standards for displaced groups' well-being should get more research attention. It should also be noted that extreme events significantly affect the well-being needs of people with health concerns regarding residential buildings. For instance, during heat waves, health risks result in morbidity and even mortality for urban residents, especially those living in poorly ventilated homes or flats without any active air-conditioning [106]. However, there were very few studies about some of the subgroups within people with health concerns.

Regarding shelter needs related to residential buildings, 15 studies focused on improper housing location and quality as well as the unaffordability of housing that cause inequities among all main vulnerable groups. Nevertheless, a detailed view of the results showed a lack of studies about the shelter needs of displaced groups. Although recent studies have tried to address the different needs of displaced groups, given the increasing rates of extreme events, more research is needed to ensure minimum standard quality of life for these groups and reduce disparities. According to the U.S. Census Bureau Household Pulse Survey, 3.3 million U.S. adults reported recent displacement from home because of disasters [107]. Integration of participatory design methods with computer models, physical prototypes, and virtual reality is an effective way to design more refugee-friendly shelters [108]. Regarding homelessness, on a single night in 2020, roughly 580,000 people were experiencing homelessness in the U.S [105]. Thus, future research studies should examine the feasibility of low-cost housing solutions and investigate the current problems and challenges regarding homeless shelters.

Access needs pertaining to residential buildings were studied in 7 papers, focusing on people with health concerns, vulnerable age groups, and people with low SES. These needs were mainly affected by physical inaccessibility in residential buildings. Although the development of new technologies to support people with health concerns and vulnerable age groups has increased, the affordability of these technologies requires more research. For example, tactile maps, indoor navigation systems, wearable computing devices, and mobile devices have been developed to help people with visual impairments in their navigation inside residential buildings [109]. Yet, more research needs to be done to develop low-cost solutions that could be adapted across these buildings.

Regarding safety needs pertaining to residential buildings, among the 5 related papers, minorities, people with low SES, and vulnerable age groups were studied. In these papers, some of the considerations in the surrounding environment and housing were studied to alleviate violence and improve safety. On the other hand, needs concerning safety have been reported in shelters for displaced groups [110], whereas, in the collected dataset, no study was found to address this need from a methodological perspective. Similarly, the studies that address safety-related inequities experienced by people with gender/sexual orientation vulnerability were limited; however, there are gender-related differences regarding safety in residential settings [111]. For instance, safety measures of housing are reported to be critical for women survivors of violence [112]. Although the feeling of living in an unsafe environment can be tackled with some solutions, such as improved lighting systems [113] in residential settings and in-between residential buildings [114], more studies are required to address the

safety needs thoroughly. Safety becomes more crucial in times of extreme events. With regard to vulnerable age groups, reduced physical and cognitive abilities hinder elderly people's quick response to disasters [115]; however, our dataset showed limited studies in the context of residential buildings. Additionally, people with health concerns, such as people with visual or hearing impairments, require more attention in times of extreme events since they possess different abilities in sensing environmental factors [116,117]. When emergencies occur, hearing and visually impaired people are more vulnerable to life risks since they have limitations in hearing warnings and recognizing exit signs. Moreover, no evidence of study on the safety needs of people with gender/sexual orientation vulnerability was reported. However, women are more at risk of death during and following disasters due to caregiving responsibilities and their likelihood of being trapped at home. Furthermore, climate disasters can cause women to lose tenure and give up economic assets, trapping them in a cycle of vulnerability. In addition, the longer-term impacts of climate disasters are more deeply felt by women due to increased caregiving burdens and the risk of gender-based violence [61].

4.3.3. Public open spaces

The presented results in Fig. 11 indicate how the 69 studies elaborated on the different needs of vulnerable groups in public open spaces. The 57 papers related to well-being needs mainly focused on how insufficient quantity, proximity, and quality of green space [77,118], as well as distribution of open spaces [119], resulted in health and well-being-related inequities among minorities, people with low SES, and vulnerable age groups, especially children and elderly people. Given the significant role of public open spaces in the well-being of different vulnerable groups, the inequities within this context were studied more extensively in previous research projects. For instance, given the soaring rates of obesity in the U.S. [120], researchers have conducted several studies about the effects of unhealthy food outlets and lack of parks on poor health conditions and sedentary behaviors [121].

In terms of access needs regarding public open spaces, the pertinent 22 papers mostly focused on the effects of physical inaccessibility on inequities experienced by vulnerable groups who require special access accommodation. In this regard, access needs of people with health concerns (people with reduced mobility in particular) and vulnerable age groups (elderly people in particular) were studied more than other groups. There was a notable focus on the uneven distribution of public open spaces, which can hinder access to minorities and people with low SES. Consideration in planning, design, and construction of public open spaces could facilitate access of different vulnerable groups and, thus, their participation in social life. For instance, given the social exclusion of people with cognitive differences, reshaping neighborhoods and cities can help this group engage more in public activities. In this regard, ensuring that the space is well-lit, with no reflections in the ground, is recommended for dementia-friendly public open spaces [122].

Considering mobility needs, the main focus of 17 papers was on people with low SES and minorities who were mainly affected by issues such as lack of walkable areas [123], exclusion in planning and engineering practices in public open spaces [73], and more. Nevertheless, there was limited or no evidence about the mobility needs of vulnerable age groups, displaced groups, and some subgroups of people with health concerns (people with visual or hearing impairments, for instance). Given the importance of social participation of people with different abilities [124,125] and the growing aging rate [97], more studies and practices are required to tackle mobility needs related to public open spaces.

Regarding safety, a few studies focused on how unsafe surrounding environments [120] and violence hotspots in public spaces [83] affect the safety needs of vulnerable groups, including minorities and people with low SES in public open spaces. While less focus was given to children in public open spaces, they have safety-related needs, especially in underprivileged suburbs with higher violence rates [120]. On the other hand, people with gender/sexual orientation vulnerability are susceptible to violence and unsafe public open spaces [126], although no evidence was found in this regard among the included publications. Less traffic exposure, shorter distances to facilities, and pedestrian infrastructure for walking and cycling are suggested to improve neighborhood safety [127].

4.3.4. Water and energy infrastructure

Well-being was identified as the only need in the context of water and energy infrastructure. As depicted in Fig. 12, the focus of 27 papers about water and energy infrastructure was on the well-being needs of different groups, including people with low SES and minorities. These inequities were mostly caused by a lack of proper water resources [128] and energy poverty [129]. Given that many people have low SES [69] and, thus, experience more severe inequities, the high number of studies about the well-being needs of this group is understandable. These needs were associated mainly with environmental health issues in the places where they live [130]. Similarly, many studies focused on how disparities in providing water and energy infrastructures affect the well-being of minorities in the U.S. context [128]. A few studies focused on the well-being needs of people with gender/sexual orientation vulnerability, whereas there are differences regarding experienced inequities in water and energy resources [131]. Moreover, displaced groups experience water- or energy-related inequities (e.g., the urban heat island, water insecurity [132]); however, no study was found on their well-being

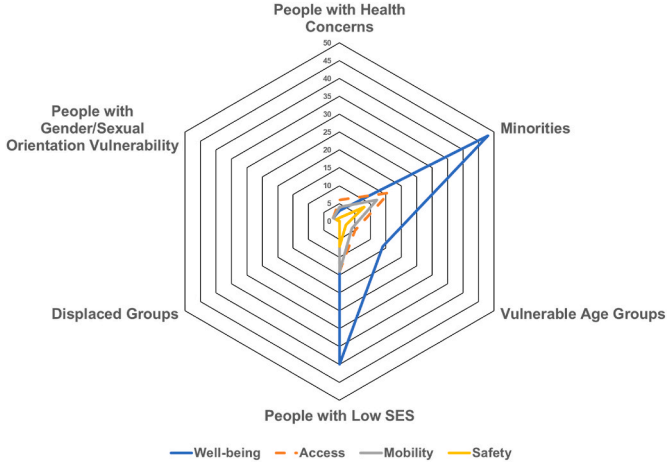

Fig. 11. Vulnerable groups and their needs related to public open spaces.

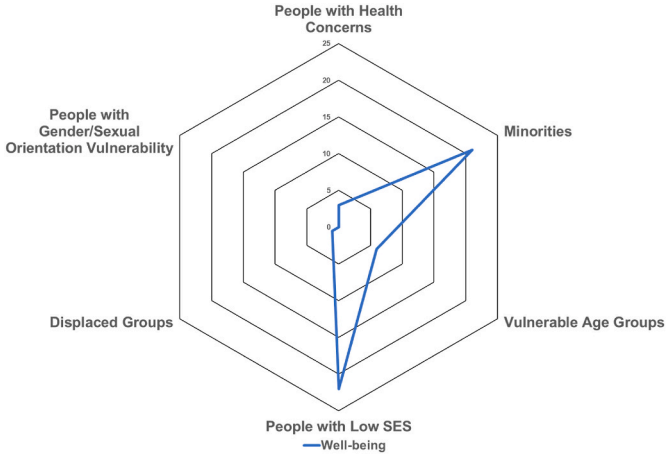

Fig. 12. Vulnerable groups and their needs related to water and energy infrastructure.

needs among the included set. Participatory approaches can help to address inequities related to the water and energy infrastructure. For instance, involving local stakeholders from different sectors and counties during the entire planning process of water infrastructure enables the exploration of tradeoffs between different groups using decision-support models [133]. It should be noted that disaster-induced disruptions in infrastructure systems, such as water and energy, could potentially affect the social vulnerability of groups in several ways. Different levels of exposure, different capacity to withstand disruptions, different access to emergency assistance to alleviate infrastructure loss, and different resources to find infrastructure service alternatives shape the vulnerability of different groups. For example, medical patients requiring regular dialysis treatments rely on clean water and electric power [103]. Given this differential vulnerability of several groups and the lack of identified research evidence in this regard, more focus should be given to addressing the inequities experienced by different groups in times of disruptions in water and energy infrastructure.

4.3.5. Commercial buildings

Well-being, access, and safety needs were identified in the context of commercial buildings across 24 papers, as shown in Fig. 13. Two-thirds of these papers elaborated on well-being needs that were affected by the uneven distribution of amenities and services [119] and environmental health issues such as air pollution [134]. Among these papers, the focus was mainly on minorities and people with low SES. However, a detailed analysis of the results unveiled the lack of studies about the well-being needs of people with health concerns, more specifically, people with cognitive differences and people with visual or hearing impairments. While the evidence on the implementation of technologies to address well-being needs was limited, some studies proposed technologies that facilitate the working experience in commercial buildings [135]. However, the inclusive usability of these technologies should be studied more. For instance, platforms for automated control over office spaces should ensure usability concerns of older workers [136]. Moreover, studying the effect of commercial buildings' physical factors on users' physiological and psychological responses and cognitive behaviors dates back to recent years [137]. Although the focus on this topic is rising (e.g., how work environments should accommodate Autistic office workers [138]), more research still needs to be done to uncover the specific challenges that affect people with different kinds and levels of cognitive abilities.

In terms of access, 8 papers have been specifically dedicated to examining the physical inaccessibility faced by individuals with health concerns, particularly those with disabilities [139,140]. However, there were limited studies about the access needs of vulnerable age groups that affect their quality of life, while some modifications can facilitate the accessibility of commercial buildings for these groups. For instance, entrances and aisles with adequate head clearance and minimal projections into the path of travel result in easier navigation for people with visual problems or those who may be disoriented by clutter. Furthermore, the implementation of lightweight doors equipped with accessible hardware enables individuals with arthritis or those relying on a cane for enhanced balance to easily open them. In cases where doors are heavier, the use of automatic and power-assisted mechanisms proves beneficial not only to individuals with reduced mobility but also to the elderly population at large [141]. Regarding safety, there was very limited focus on different vulnerable groups, while the relationship between perceived safety and the design of entrance/exits and immediate surroundings in commercial areas was studied in some cases [142,143].

4.3.6. Educational buildings

As shown in Fig. 14, studies related to educational buildings focused on well-being, access, and safety needs. Inequities related to well-being needs within the educational building's context were studied in 9 papers, focusing on minorities, people with low SES, and vulnerable age groups. Low air quality in public schools was one of the main studied issues [144]. While not much focus was given to the well-being needs of people with health concerns, including children with cognitive differences, inclusive design practices for children with special needs, such as those diagnosed with Autism and ADHD, are crucial while designing educational buildings [145]. Children and teenagers, as one of the main occupants of educational buildings, lack the sufficient capability to identify and deal with environmental health risks [146,147]. Despite the interdisciplinary nature of investigating the impact of indoor environmental quality (IEQ) factors on respiratory diseases such as Asthma and sedentary behaviors, which contribute to increased obesity rates, the current lack of relevant evidence underscores the need for further research pertaining to the well-being of children with health conditions [76,148,149]. Additionally, more research attention should be devoted to the well-being needs of young adults occupying higher education buildings. For instance, while the focus on the well-being needs of people with cognitive differences is rising [150], there are unanswered research questions in terms of providing cognitive-friendly environments without excluding learners with different cognitive abilities from their peers.

With regard to access requirements related to educational buildings, a set of 5 papers has been identified, primarily concentrating on the disparities faced by individuals with health concerns, such as children who experience limited mobility as a result of physical inaccessibility of educational structures [151]. Nonetheless, it is imperative to consider the construction of cost-effective schools that are designed to accommodate individuals with disabilities. Moreover, it is crucial to prioritize

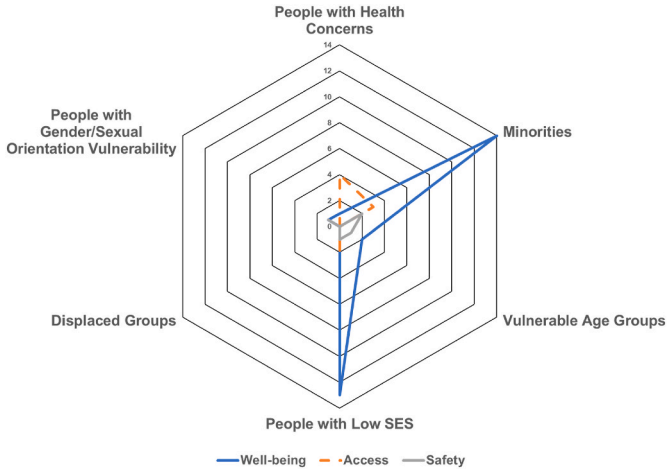

Fig. 13. Vulnerable groups and their needs related to commercial buildings.

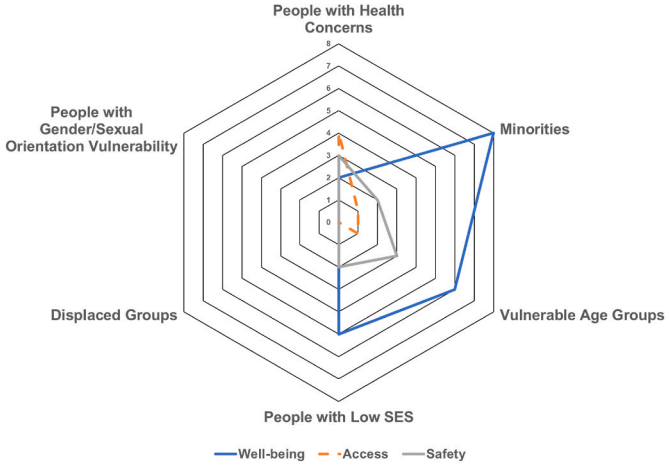

Fig. 14. Vulnerable groups and their needs related to educational buildings.

the convenient geographical accessibility of educational facilities in areas inhabited by low SES groups and minority populations through urban planning and zoning practices [152].

Regarding safety in educational buildings, compliance with hygiene standards and providing play areas can prevent violence and increase safety [153]. Furthermore, to cater to the safety requirements of vulnerable age groups, such as children, in educational structures, the proposal of implementing structural retrofits and architectural renovations as a means of mitigating disaster risks has been put forth [154]. Moreover, studies showed that the physical features of educational settings could affect the safety and security of students with learning disabilities [155]. Additionally, educational curricula and programs can play a significant role in equipping learners with the necessary skills for emergency response in educational buildings [156]. The evacuation behavior of occupants of educational buildings should be explored across different demographics to understand how these differences affect the emergency response [157].

4.3.7. Healthcare facilities

According to Fig. 15, vulnerable groups and their needs were studied in 12 publications related to healthcare facilities. The well-being needs of multiple groups were discussed in 9 publications, mainly through the lens of the environmental health approach (e.g., air pollution analysis in healthcare environments [148]) and zoning approach (e.g., uneven distribution of health centers and weak connectivity [158]). Healthcare facilities accommodate people who seek health treatment and social protection services, and thus, it is expected that most of the related papers cover the well-being needs. However, given the low focus on people with gender/sexual orientation vulnerability and their special well-being needs regarding healthcare facilities, more research needs to be conducted in this regard.

Moreover, 7 papers focused on access needs regarding healthcare facilities. Design considerations to overcome physical barriers [159], integrated inclusion of certain groups [159], and spatial inaccessibility due to uneven distribution of healthcare facilities [158] were the most studied underlying factors that cause access-related inequities in healthcare facilities. While the focus of these studies was mainly on people with health concerns, people with low SES, and vulnerable age groups, the access needs of displaced groups were not explored extensively. For instance, although improved access to healthcare services can tailor care to the needs of displaced groups such as migrants, the evidence of migrants' geographical access to healthcare is scant [160]. To that end, more research needs to be conducted in this regard. Relocation of existing healthcare facilities or the development of new healthcare facilities can address geographical inaccessibility [161]. The investigation of safety needs was lacking in the included publications pertaining to healthcare facilities, despite the crucial role these facilities play in shaping occupants' sense of safety. For instance, the architectural design of pediatric rehabilitation therapy rooms can affect safety feelings among children with Autism [146]. Design considerations such as avoiding the use of slippery surface materials and providing one-way views through windows could provide the feel of safety, particularly among vulnerable groups [162].

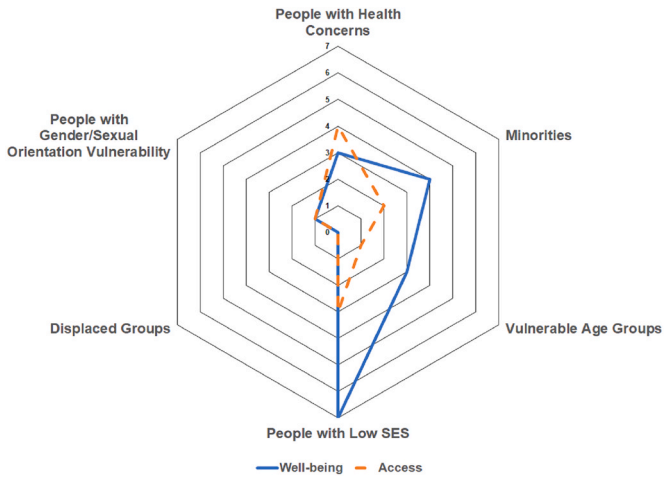

Fig. 15. Vulnerable groups and their needs related to healthcare facilities.

4.4. Analysis of subgroups in the U.S

Based on the detailed subcategories of the studied vulnerable groups in the built environment, more specific subgroups were identified among the included studies within the U.S. context. The summary of publications associated with subgroups and their needs is presented in Table 3. This table symbolically demonstrates the relative research attention to the different needs of vulnerable groups. The population of each subgroup is included in Table 3. U.S. Census [69,164], Centers for Disease Control and Prevention (CDC) [93,165–170], NIH [171], and other references [172–177] were used to extract population data.

According to this table, certain vulnerable groups have received more extensive research attention, such as individuals with low income, racial-ethnic minorities, and those with reduced mobility. Additionally, the different needs of children and youth, residents of deprived areas, elderly people, and women have been a matter of focus in previous studies. Conversely, there is a notable dearth of research on the needs of other vulnerable groups, indicating the potential areas for further investigation. Specifically, the needs of individuals with cognitive differences, including Autism, Attention-Deficit/Hyperactivity Disorder (ADHD), Dementia, and Down Syndrome, have been relatively understudied. Additionally, future research endeavors could prioritize exploring the needs of pregnant women, individuals with visual or hearing impairment, those facing challenges with self-care and independent living, as well as individuals with obesity. Moreover, the lack of research evidence concerning the needs of individuals with gender/sexual orientation vulnerability, indigenous people, refugees, and individuals experiencing homelessness underscores the urgent need for research attention in these areas. As can be concluded from Table 3, the population of subgroups is highly correlated with the varying number of publications on different subgroups.

The U.S. has the highest Gross Domestic Product (GDP) [178] and provides funding for research projects more than any other country [179]. While certain groups have been the focus of more frequent research in the U.S., the exploration of the needs of many other groups has been comparatively limited. For instance, considering the prevalent phenomenon of homelessness in numerous metropolitan cities along with the increasing influx of refugees from various parts of the world, further research is warranted to address the challenges pertaining to affordable housing and the improvement of physical environments across homeless shelters and refugee camps. Indigenous populations, historically subjected to marginalization, also necessitate heightened research attention. Notably, they encounter obstacles related to the safety and accessibility of drinking water, as well as governance and control of water sources in certain regions [180]. As another example, since the obesity rate is increasing in many U.S. cities due to unhealthy food environments and barriers to physical activity in the built environment [120], more studies should be conducted to highlight and address the importance of providing healthy and activity-friendly neighborhoods. The needs of people with Asthma have also received attention within the built environment context since the higher rates of Asthma can be correlated with higher rates of public housing and deteriorating housing conditions [148].

Planning and design practices affect the quality of life for people with different cognitive differences. For instance, the type of lighting, lighting color, wall color, amount of noise, and texture of materials shape the experience of individuals with Autism, ADHD, and Down's Syndrome in living, working, and learning environments [181,182]. Although more

Table 3
Research gaps in terms of the different needs of different vulnerable groups.

Name of Main Groups	Name of Sub-Groups	Population Rate in the U.S.	Needs				
			Well-being	Access	Mobility	Shelter	Safety
People with Health Concerns	People with Visual Impairment	4.80%	3	7	6	0	1
	People with Hearing Impairment	6.10%	3	5	4	0	1
	People with Autism	2.78%	2	2	2	0	1
	People with ADHD	4.40%	2	2	1	0	0
	People with Dementia	1.75%	1	3	2	0	0
	People with Down's Syndrome	0.14%	1	1	0	0	0
	People with Reduced Mobility	12.10%	10	23	20	3	4
	People with Selfcare Difficulty	3.60%	3	3	1	0	0
	People with Asthma	7.80%	10	0	0	0	1
	People with Obesity	41.90%	2	0	1	0	2
	People with Independent Living Difficulty	7.20%	1	0	0	0	0
	Pregnant Women	1.08%	0	0	0	0	0
Minorities	Racial / Ethnic Minorities	40.70%	87	16	31	1	15
	Indigenous People	1.00%	1	0	0	1	0
People with Gender/Sexual Orientation Vulnerability	Women	50.50%	11	5	6	1	3
	People with Sexual-Orientation Vulnerability	5.60%	2	1	1	1	0
Vulnerable Age Groups	Children & Youth	40.00%	32	2	10	1	6
	Elderly	16.80%	17	8	13	5	3
People with Low SES	Low-Income People	11.60%	60	16	28	3	15
	Residents of Deprived Areas	21.10%	21	5	9	2	3
Displaced Groups	Refugees	0.94%	0	0	0	0	0
	Homeless People	0.18%	1	0	0	0	1

Relatively less studied topics — Relatively more studied topics

research has been dedicated to these groups and their specific needs in recent years, there are still more questions regarding how to address the variety of preferences of people with different levels and types of disabilities altogether without excluding them from others and without affecting other groups preferences in the shared environments adversely. Moreover, given the relatively low attention to addressing the needs of people with visual or hearing impairments, more research needs to be conducted. The presence of infrastructural barriers that hinder the path of people with visual impairments makes their experience challenging, both from a physical and emotional perspective,

leading to quite negative judgments for all the elements (i.e., sidewalk, crossing, stairs, parking, street) of the urban area [125], and therefore, more consideration should be given in design, construction, and operation of built environments. The prospective research should consider the sensory differences while proposing new technologies and solutions that rely on interactions through certain senses. To that end, research on the effective integration of new technologies, such as the Internet of Things (IoT), with built environments can assist people with visual or hearing impairments to move autonomously to the nearest safe place during emergency scenarios [183]. The built environment could also affect the needs of pregnant women. For example, the risk of preterm birth can be associated with NO2 concentrations in built environments [184], and thus, air quality plays a significant role in alleviating these risks. Modification in the built environment could reduce the inequities experienced by people living in deprived areas. For instance, urban regeneration with changes to the built environment or regenerating large areas of deprived areas in cities (e.g., housing demolition and improvement and new community buildings) could help in achieving equity goals in society [185].

5. Research gaps

The suggested gaps could give insights to researchers who are interested in addressing the cross-disciplinary inequity issues in various built environments. As discussed earlier, the needs of individuals and groups may vary in built environments, which brings challenges regarding designing for all. Creating equity-based environments requires knowing how these competing needs change over time in a continuous way [186], and thus, multiple variations of human needs exist in the built environment. For instance, the emotional state, as one of the indicators of health and well-being, varies with different ranges of IEQ factors [187]. Moreover, the physical components of built environments may vary over time (e.g., the CO_2 level and humidity). These varying needs and physical components require continuous assessments of adaptation in physical spaces to evaluate the efficiency of equity-oriented measures. Here, we list a few research questions based on the research gaps identified in this study.

5.1. Group-related research questions

- How can the competing objectives of different individuals and groups be addressed in built environments?
- How can politicians, planners, and engineers contribute to built environments that meet the wide range of diverse human needs, particularly those of society's most vulnerable members?
- How should the newest versions of building standards and guidelines focus on addressing the needs of vulnerable groups?
- What are the obstacles to the decision-making, planning, design, construction, and operation of low-income housing for those with emergent needs?
- What measures need to be taken to provide affordable housing for homeless groups?

5.2. Built environment-related questions

- How is equity in built environments quantified?
- How can we design our built environments to reduce the severity of inequities across all groups simultaneously?
- What can be improved in design standards, construction practices, and operational guidelines of built environments to alleviate inequities?
- How can built-environment-oriented measures be prioritized to address the current challenges in war zones and areas affected more by climate change?
- How can cross-disciplinary collaborations between professionals from different disciplines (e.g., engineering, design, planning, social science, cognitive science, and more) help handle challenges toward achieving equity goals in built environments?
- How can new approaches such as Occupant-Centric Building Design and Operation [188] and Human-Building Interaction [189] help in achieving equity goals in built environments?
- What are the built-environment-related challenges in homeless shelters?

5.3. Needs-related questions

- How does adherence to equity objectives affect the balance between prior objectives in the built environment, such as sustainability, affordability, resiliency, and health?
- How can governments and international organizations encourage researchers to focus on inequity issues in the built environment in the least developed and developing countries?
- Although research projects on inequity issues in built environments are increasing, given the high rates of existing inequities worldwide, what are the barriers to allocating more funding resources in this regard?
- How can we facilitate the safety of people with different kinds of disabilities through built-environment-related measures in emergency scenarios?
- How can the needs of displaced groups be rapidly addressed given the increasing number of extreme events (e.g., floods, hurricanes, wildfires)?

It should be noted that research efforts on addressing inequities in built environments can be facilitated by utilizing participatory approaches, which can offer significant advantages for empowering urban planning principles from a sustainability perspective. By involving communities in the decision-making process, participatory methods can help identify and address specific challenges that hinder access to public spaces and urban development initiatives. This collaborative approach ensures that the concerns of various stakeholders, especially those from vulnerable groups, are taken into account [190]. Furthermore, participatory methods can facilitate a more balanced allocation of resources and investments, particularly in areas like affordable housing and essential services. This, in turn, contributes to the overall sustainability and equitable development of urban environments [191].

6. Limitations

While this study offers contributions to the topic of equity in the built environment, the findings should be interpreted with certain limitations in mind. First, among the vast variety of issues related to built environments that affect human needs, this study could only identify the main inequity issues without being able to categorize and identify a detailed list of all inequity issues for different types of built environments. These detailed lists require in-depth analyses of each type of built environment to capture the issues that cause inequities among different vulnerable groups. Second, the presented categorization, results, and discussions for vulnerable groups encapsulate most of the groups who bear inequities. However, given the high number of specific groups, particularly people with health concerns, more detailed analyses should be conducted to identify their less-explored needs. Similarly, this study captured the most basic needs of users of the built environment. Nevertheless, studying inequities around other needs, such as comfort and privacy, could provide a more collective viewpoint on inequities in the built environment. Though important, the intersecting vulnerabilities were not a part of this study's scope, and future studies ought to explore comprehensively how these intersections could affect inequities in the built environment. Next, it is important to acknowledge that the results and patterns presented in this study represent larger trends, and while efforts have been made to include relevant articles, it is possible that some articles were not included. While the number of publications

was considered as the main criteria for distinguishing research focus across study dimensions, the variations in research focus could have other underlying factors such as the population of vulnerable groups, the relative importance of needs in the viewpoints of built environments' stakeholders, the unevenness of budget availability throughout different types of built environments, and selection bias in the research design. Finally, the included publications were written in English and were focused on inequities in the U.S., and the comparative analysis throughout the paper was conducted using this inclusion criterion. Nevertheless, incorporating non-English and/or publications from outside the U.S. within the corpus of collected studies has the potential to broaden our understanding of equity within the built environment. This inclusion would contribute to a more comprehensive and nuanced analysis, encompassing both unidimensional and cross-dimensional assessments based on the BGN model, thereby enriching our insights into the subject matter on an international level.

7. Conclusions

Given the dynamicity of our world, where crises (e.g., pandemics, wars, lack of water and energy resources, inadequate housing, and the frequent cycles of droughts and floods) worsen inequity in all aspects, it is vital to shift paradigms in current built environmental practices to address the key needs of different vulnerable groups. To begin this paradigm shift, this study aimed to identify the main areas of inequity in the U.S. context. The present study demonstrates the necessity of taking appropriate research measures to address inequity issues regarding built environments within the U.S. context. As preliminary steps, the definition of equity in the built environment was provided, and the BGN model was introduced to integrate the key dimensions of this definition. The systematic review used the PRISMA 2020 statement, which led to the inclusion of 232 papers for data extraction and synthesis. The temporal analysis confirmed a growing trend in studies about inequities in the built environment. The geographical analysis of the results uncovers the necessity of defining and conducting research in regions with higher social vulnerability indices. According to the results, inequities regarding transportation facilities, residential buildings, and public open spaces were explored more in scientific publications, while there was less focus on inequities with regard to water and energy infrastructure, commercial buildings, educational buildings, and healthcare facilities. Regarding the needs, well-being, mobility, and access were more associated with the inequities in the previous studies, while there was less inequity-related evidence on shelter and safety needs. From the group perspective, minorities, people with low SES, people with health concerns, and vulnerable age groups got more attention, while inequities experienced by people with gender/sexual orientation vulnerability and displaced groups were explored relatively less. Based on in-depth analysis, although the needs of all vulnerable groups still deserve continuous research attention, more specifically, the needs of refugees, homeless people, people with visual or hearing impairments, people with cognitive differences, children, and women in different built environments could be explored more by future studies.

Reducing environmental health issues through providing accessible fresh water, conserving and creating green spaces, relocating polluting facilities, and holistic zoning practices could alleviate inequities related to environmental risks. The development of low-cost housing solutions with standard quality and enhancing the safety of neighborhoods could protect vulnerable groups in the built environment. On the other hand, integrating mobility, sensory, and cognitive differences into design considerations and emergent technologies, facilitating accessibility through removing physical barriers and increasing connectivity, and considering the gender differences in all phases of the built environment life cycle are helpful in facilitating the participation of vulnerable groups in social life. Focusing more on human needs in building guidelines and standards can also contribute to equity goals in the built environment. Nevertheless, addressing the inequities experienced by vulnerable groups comes with certain challenges in practice, particularly in shared spaces where the needs and objectives of occupants might be contradictory to each other. Equity in a built environment is a path in which the suggested adaptations and several other possible modifications should be pursued in more detail. The potential challenges in this path could be addressed through interdisciplinary collaborations with all stakeholders of the "equity-based" built environment.

CRediT authorship contribution statement

Mirmahdi Seyedrezaei: Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization. **Burcin Becerik-Gerber:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Mohamad Awada:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Conceptualization. **Santina Contreras:** Writing – review & editing, Supervision, Conceptualization. **Geoff Boeing:** Writing – review & editing, Supervision, Investigation, Conceptualization.

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.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.buildenv.2023.110827.

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