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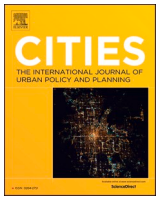

Spatializing urban perception: Subjective indicators for participatory GIS☆

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ABSTRACT

Urban planning continues to lack robust methodologies that meaningfully incorporate citizen perspectives. Traditional participatory tools—such as assemblies or top-down consultations—have proven insufficient to capture urban perception, a key element for understanding how people experience everyday environments. In response, digital platforms based on Public Participation Geographic Information Systems (PPGIS)—understood as geospatial tools for mapping citizen perceptions—have emerged as promising mechanisms to reconnect institutional decision-making with community experience. These platforms offer new possibilities for expanding participation and generating spatial data on urban preferences.

This study aims to identify the main subjective indicators used to assess citizens' perceptions through PPGIS platforms. A scoping review of 98 academic papers was conducted, with in-depth analysis of 21 studies, to develop a conceptual model synthesizing current theoretical and methodological contributions. The results include: (1) a conceptual model for assessing urban perception through PPGIS; (2) a classification of subjective and objective indicators; (3) a review of recruitment strategies to enhance engagement; and (4) a typology of study fields where these approaches are applied.

By addressing the integration of subjective data in spatial decision-making, this research advances theoretical foundations for digital participation in urban planning and suggests future applications in empirical contexts using GIS and machine learning techniques.

1. Introduction

There is consensus regarding the existence of two complementary approaches to studying the quality of life in communities: the objective or technical approach, based on the collection of quantifiable indicators; and the subjective or perceptual approach, based on individuals' perceptions of their living conditions (Boira, 1992; Gavrilidis et al., 2016; Sottini et al., 2018). In general terms, measurements of the urban environment conducted from an objective approach are developed using georeferenced databases based on geographic information systems (GIS) or through expert on-site observations with technical auditing tools. In contrast, qualitative measurements are based on collecting citizens' perceptions regarding their impressions of the inhabited environment (Brownson et al., 2009).

However, given that the study of the physical environment is easily measurable through quantitative indicators, regulatory frameworks tend to rely mostly on these objective tools to assess urban quality. This emphasis often limits the ability of institutions and professionals to incorporate the experiences, perceptions, and needs of those who inhabit the city. As a result, subjective indicators remain underrepresented in planning processes (Brown, 2004; Brownson et al., 2009; Sabri et al., 2016) leading to missed opportunities for implementing evidence-based design strategies (Adedeji et al., 2018). This asymmetry has become increasingly problematic in urban contexts marked by inequality, fragmentation, and mistrust in institutions.

In line with these concerns, recent studies have advocated for combining subjective indicators with advanced modelling techniques to better understand the relationship between environmental quality, perceived satisfaction, and urban well-being (Bose et al., 2023; Roy et al., 2024). These approaches exemplify the growing relevance of perception-based frameworks in urban research and their potential to inform planning in rapidly urbanizing contexts.

Despite this trend, many studies emphasize that information regarding the built environment and citizens' perceptions are equally important to assess urban quality (Carmona, 2019; Dempsey, 2008; Moeinaddini et al., 2020; Van Kamp et al., 2003). Yet, traditional

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participatory processes—such as consultations or public hearings—have been limited in their ability to systematize citizens' perceptions at scale and translate them into actionable planning insights. Typically implemented under "top-down" logic, these processes tend to be sporadic and rarely integrated into the broader planning apparatus (Brown & Kyttä, 2014; Haklay et al., 2018; Kahila-Tani et al., 2019; Lawson et al., 2022). This makes it necessary to create new 'bottom-up' data production methods to better understand citizens' preferences and behaviors (Brown & Kyttä, 2014; Marti et al., 2019; Saadallah, 2020).

In this context, Public Participation Geographic Information Systems (PPGIS) have emerged as powerful tools to bridge the gap between citizens and institutions. PPGIS refers to digital platforms that support the geolocation of citizens' perceptions and their integration with spatial decision-making, enabling the co-production of urban knowledge. These systems draw on advances in Information and Communication Technologies (ICTs) and the expansion of smartphones and internet access, which now facilitate new forms of digital participation (Afzalan & Muller, 2018; Chambers, 2006; Falco & Kleinhans, 2018).

However, despite the growing use of PPGIS and digital mapping technologies, there is no consolidated framework that identifies and organizes the subjective indicators collected through these platforms. Most research focuses on technical infrastructure, usability, or case study evaluations, but lacks a conceptual synthesis of indicators that could guide policy-relevant knowledge derived from citizen perceptions.

This paper addresses that gap by offering a scoping review of the international literature, aiming to systematize the main frameworks and subjective indicators used to collect citizens' perceptions about their urban environments through PPGIS. The review examines 98 academic articles, of which 21 were selected for deeper analysis based on defined inclusion criteria.

Specifically, the objectives of this research are: (1) Establish a general conceptual framework to analyze citizens' perception of their urban environment with the support of PPGIS; (2) Identify the main indicators to operationalize the conceptual framework; (3) Describe different study fields in which this framework and subjective indicators are being applied. As a scoping review, this paper does not present new empirical findings, but rather offers a conceptual contribution that may inform future applications, including hybrid methods combining geospatial analysis and machine learning to detect perception-based patterns.

In doing so, the paper contributes to the growing conversation around how subjective and objective indicators can be meaningfully integrated in urban governance systems. It advocates for participatory methods that go beyond symbolic inclusion and build concrete channels for experiential knowledge to shape decision-making.

The article begins with a theoretical review of traditional participatory approaches and perceptual studies, followed by a description of research methods used to conduct the scoping review and process the data. The results offer: (1) a conceptual framework for understanding urban perception through PPGIS; (2) a synthesis of subjective and objective indicators to operationalize the framework categorized by perceived environment, sociodemographic factors, and urban structure; (3) an overview of recruitment methods to enhance participation, and finally (4) a description of the main study field in which digital citizens participation is being used. Finally, the discussion reflects on the need to strengthen theoretical foundations for participatory urban technologies, and reflects on the opportunities to move from smart cities to smart citizens approaches by outlining potential paths to switch from data-rich to citizen-centered planning.

2. Theoretical framework

Over the past decades, a growing body of literature has emphasized the limitations of traditional approaches to urban planning that rely exclusively on objective data and expert-driven decision-making. Despite early calls to recognize the importance of subjective experiences in shaping urban life (Jacobs, 1967; Lynch, 1960), institutional planning frameworks have often marginalized experiential knowledge in favor of quantifiable indicators (Van Kamp et al., 2003). However, a new wave of interdisciplinary research — including environmental psychology, human geography, and participatory GIS — has opened possibilities for integrating citizens' perceptions into the planning process. This theoretical framework explores the reasons behind the persistent invisibility of subjective indicators, the evolution of methods to measure urban perception, and the potential of PPGIS to act as a counter-methodology within dominant knowledge-power structures in urban governance.

The limits of traditional participatory processes and the marginalization of subjective knowledge in traditional participatory processes — including town hall meetings, citizen consultations, and workshops (Rall et al., 2019) — have contributed to the invisibilization of subjective data in urban planning. These methods have revealed excessive participation of active minorities and organized interest groups while the 'silent majority' remains largely underrepresented (Brown & Kyttä, 2014). Long meetings limit the possibility of caregivers or long-shift workers to participate, hindering large segments of the population from engaging in the debate (Kahila-Tani et al., 2019). There is also a noted deficiency in the quality of analysis and the invisibility of the data obtained, which is not fed back to the population (Haklay et al., 2018; Kahila-Tani et al., 2019). Furthermore, these processes demand a significant amount of resources and time from public administration (Haklay et al., 2018). These difficulties have resulted in the historically minimal and non-binding influence of participation processes in urban planning decisions (Haklay et al., 2018), generating a 'systemic feeling of injustice and lack of trust' identified as endemic in the literature on citizen participation processes (Lawson et al., 2022).

The marginalization of subjective knowledge in urban planning is not merely a methodological issue but an epistemological one. Urban planning, as a technocratic discipline, has historically privileged "expert" forms of knowledge — often male, white, and technocratic — over the lived experiences of diverse communities (Mouratidis, 2021; Pérez Sanz & Gregorio Gil, 2020; Arias & Muxí, 2018). This exclusion reflects a broader struggle over what counts as legitimate knowledge in planning practice, where emotional, sensorial, or relational data are often dismissed as anecdotal or unscientific. In this sense, PPGIS offers the opportunity to reclaims the legitimacy of subjective and place-based knowledge, challenging dominant structures of power and epistemic authority in urban governance (Afzalan & Muller, 2018; Falco & Kleinhans, 2018).

Despite these objective tendencies in urban planning, there are many reasons to support the need to involve citizens' perception of their built environment in the decision-making processes of a city. (1) Regarding quality, some authors declare that the objective characteristics of a place do not represent its true quality, since quality is not determined only by the physical form, but by the perception people have of their environment (Van Kamp et al., 2003). (2) Others argue that the new paradigm of modern citizens is feeling, and city administration needs to consider emotional data to identify places that need to be recovered or saved, to guarantee citizens' subjective well-being (Nenko & Petrova, 2018). (3) Finally, many thinkers have historically proclaimed the need for public participation in the making of communities (Daher et al., 2021; Fainstein & Fainstein, 1972; Lawson et al., 2022; Sui et al., 2013; Szarek-Iwaniuk, 2020), and considering societies are built from dynamic bottom-up social relationships (Jacobs, 1967), the public sphere must facilitate the emergence of institutional mechanisms for visualizing and valuing the subjectivity and experiences of human life (Gehl, 2010; Liu et al., 2017).

Nonetheless, efforts to introduce more inclusive and participatory approaches often confront resistance from entrenched governance structures. Public officials may lack the technical capacity or political will to incorporate participatory data meaningfully, and existing regulations frequently do not mandate its use in planning decisions. This leads to what some scholars consider as *datafication without influence* — the production of participatory data that ultimately fails to impact

policy due to institutional inertia or technocratic path dependency (Cardullo & Kitchin, 2019; Broomfield & Reutter, 2022).

Perceptual studies aim to understand the cognitive and emotional processes by which individuals interpret and interact with their environment (Bailly, 1979) linking the formal images of the city with the particular symbolic constructions of each individual (Boira, 1992). Foundational works, such as those by Lynch (1960), introduced formal elements — paths, edges, nodes — shaping the mental image of cities. However, another scale of formal elements shapes the everyday environment, such as shop windows, decorations, or passersby, which also determine the individual urban experience (Rimbert, 1973). These relations between environment and perceptions have traditionally been studied through tools such as cognitive maps and likert scales, allowing researchers to spatialize and quantify subjective impressions (Downs & Stea, 1973; Vara, 2008).

Disciplines such as Environmental Psychology, Emotional Geography, and Environmental Perception have provided key insights into this domain (Lian et al., 2020; Roth, 2000; Vara, 2008). One particularly relevant contribution is the transactional person–environment approach, an established framework in environmental psychology that posits a dynamic, reciprocal relationship between individuals and their surroundings (Gibson, 1979). Rather than seeing perception as a passive reception of external stimuli, this approach emphasizes that people actively co-construct the meaning and significance of spaces through everyday experience (Samuelsson et al., 2018).

Despite the richness of these perspectives, several obstacles have prevented their mainstream adoption in urban planning. (1) Firstly, the influence of individual and emotional experiences in urban perception studies has made it difficult to standardize measurements and interpret results (Marques et al., 2020), keeping urban perception mainly focused on cognitive aspects, where psychological approaches prevail over urbanistic ones (Gifford, 2014). (2) Secondly, the dynamic interaction between the individual and the environment shows a constantly changing relationship, which complicates data analysis over time (Marques et al., 2020). (3) Urban perception conditioned by climatic factors, cultural practices, and elements of urban comfort, presents difficulties in measuring and quantifying (Peng et al., 2021). Moreover, historically dominant paradigms in urban analysis have favored morphological and technical indicators, sidelining experiential data as too subjective or "soft" for planning purposes.

However, recent technological developments — particularly the proliferation of ICTs and mobile devices — have expanded the possibilities of recording geolocated perceptions at scale. PPGIS platforms offer spatial interfaces that allow citizens to register their affective responses to specific places, thus enabling a finer-grained understanding of urban experience (Brown, 2004; Haklay, 2013; Kyttä et al., 2016). These methods are opening new strategies for citizens' participation processes, based on citizen science or digital participatory mapping approaches (Brown, 2004; Haklay, 2013; Kyttä et al., 2016; Laatikainen et al., 2015), enhancing the complexity and possibilities of articulation between top-bottom and bottom-up tactics to urban planning (Nenko & Petrova, 2018), and allowing citizens to become actively involved in public consultation processes (Szarek-Iwaniuk, 2020).

Recent studies have also explored the integration of subjective well-being and environmental exposure in complex urban settings using PPGIS, particularly in the Global South. For example, Roy et al. (2024) applied geographically weighted techniques to map and validate a composite Urban Well-Being Index in Darjeeling, India, demonstrating the potential of combining spatial and perceptual data to guide planning decisions in topographically challenging contexts. Similarly, Bose et al. (2023) employed integrated IPA–SEM modelling to assess satisfaction and loyalty in relation to urban sustainability indicators in Siliguri, India, reinforcing the importance of public perception in sustainability-oriented governance.

Beyond practical limitations, the marginalization of subjective indicators in planning also reflects a deeper epistemological bias. Planning has historically prioritized expert-driven, technocratic knowledge—often sidelining everyday experiences, embodied practices, and non-quantifiable forms of knowing (Mouratidis, 2021; Pérez Sanz & Gregorio Gil, 2020). This epistemic hierarchy reinforces forms of power that privilege institutional actors over community voices, making participatory processes vulnerable to tokenism, failing to shift decision-making logics (Rall et al., 2019; Kahila-Tani et al., 2019). In this context, PPGIS and digital participatory tools can be interpreted not only as methodological innovations, but also as counter-hegemonic devices that challenge dominant paradigms by making perceptual and experiential knowledge visible and spatially legible (Brown & Kyttä, 2014; Goodchild, 2007; Haklay, 2013; Sui et al., 2013). This critical perspective situates the role of digital mapping within broader debates in human geography and planning theory, positioning it as a potential tool to democratize urban governance.

In this sense, PPGIS acts both as a data-collection mechanism and as a bridge between experiential knowledge and spatial decision-making, challenging epistemic hierarchies and reimagining planning as a participatory, dialogic practice. As such, this theoretical framework serves as the foundation for the conceptual model proposed in this article, which aims to organize subjective indicators of urban perception in a structured, operationalizable form applicable in digital participatory contexts.

3. Materials and methods

This article presents the results of a scoping review conducted following the PRISMA-ScR protocol, focusing on academic literature published in the Web of Science and Scopus databases. The search strategy combined three core concepts — *urban environment*, *citizen perception*, and *digital platforms* — each expanded with seven synonymous or related terms and articulated through Boolean operators. The search yielded a total of 98 academic papers.

The scoping review approach was selected due to its suitability for synthesizing knowledge across fragmented and interdisciplinary fields. Given the diversity of theoretical and methodological perspectives on urban perception and participatory geospatial tools, this method allows for the systematic identification of patterns, recurring variables, and knowledge gaps, without seeking to produce generalizable empirical findings. This aligns with the conceptual aim of the study: to construct a transferable analytical framework based on a synthesis of existing literature.

Four criteria were applied to the review of these articles ($n = 98$) to select the final set of works to be analyzed; The criteria were: (1) relevant urban scale, including city, neighborhood or place; (2) works using digital platforms for data collection; (3) studies focused on a citizen participation approach; and (4) excluding those investigations with a focus on mobility. As a result of this filter, 21 articles were obtained. For more information on this methodology, review the article by Anonymous (2022).

This process was followed by an inductive strategy of literature-based analysis. Recurring concepts and variables were extracted from the reviewed articles and grouped thematically to define core components and their interrelations. This logic allowed us to move from individual theoretical frameworks to a broader conceptual structure suitable for application in other contexts. The resulting was used to construct the conceptual model presented in this article (Fig. 1), based not on original theorization but on a synthesis of the literature (Anonymous, 2022).The 21 selected articles were analyzed in depth to extract and categorize the following dimensions: conceptual and methodological approaches, subjective and objective indicators considered in the study, consulted users, recruiting methods, rewards techniques, and study field related to each publication. All these aspects were registered in an Excel database (see *Supplementary File 1)*.

To move from article-level data to the classification of indicators aligned with the conceptual model, the Excel database was structured in

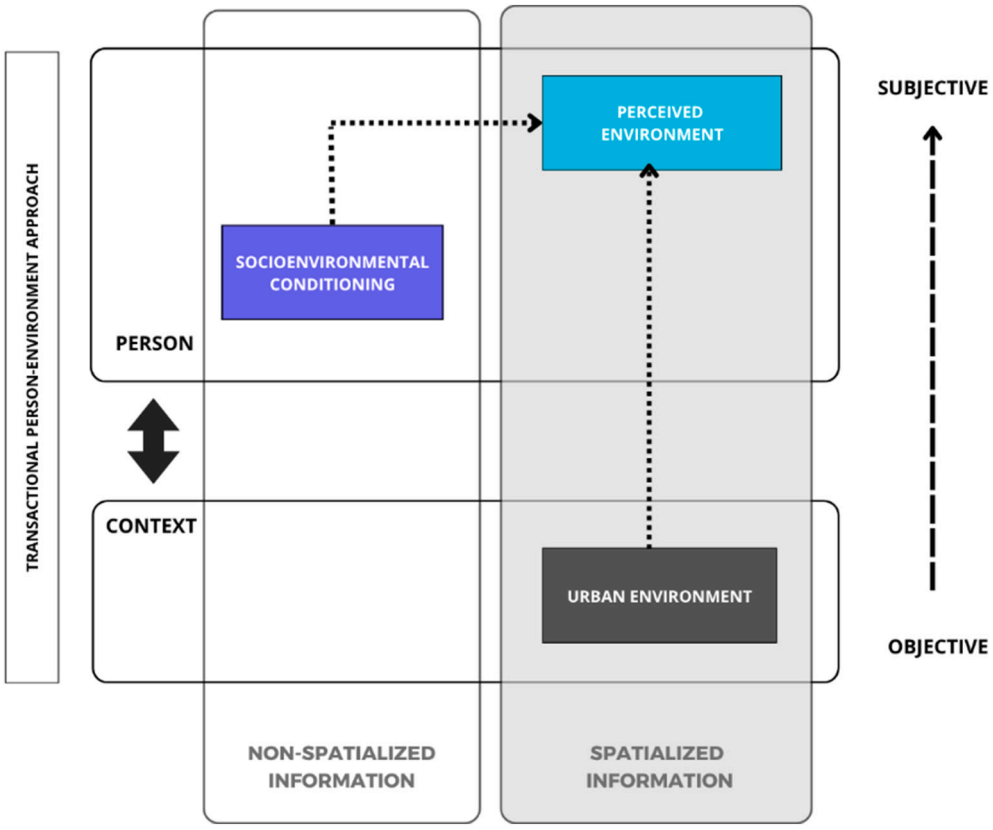

Fig. 1. Conceptual model to assess urban perception.

three interconnected sheets:

1. **General information sheet**: This sheet compiles metadata for each article, including authorship, country of study, spatial scale, type of space analyzed, and the main study field in which the research was conducted.
2. **Conceptual and methodological approaches sheet**: This sheet identifies the theoretical and methodological frameworks declared by each article as the foundation for studying urban perception through PPGIS. These elements were categorized through distinct columns to facilitate cross-comparison.
3. **Indicators and operational dimensions sheet**: This sheet records all subjective and objective indicators used in each study and assigns them to one of the three analytical domains proposed in the model: **(a) socioenvironmental conditionings**, **(b) perceived environment**, and **(c) urban environment**. In addition, this sheet includes information on consulted users, recruitment strategies, and incentive mechanisms.

Each paper was reviewed in full to extract indicators and operational elements relevant to the three domains. It is important to note that individual articles could contribute multiple indicators to a single domain—or none at all—so the total number of indicators identified exceeds the number of studies reviewed. A comprehensive description of the analytical process applied to each article is available in *Supplementary File 1*.

Following data entry, we conducted a **frequency and recurrence analysis** to identify the most commonly used indicators in each of the three domains. These frequencies were visualized through bar charts, allowing us to detect patterns and concentrations that supported the development of the indicator list presented in the results. A similar procedure was used to analyze trends in recruitment methods, user profiles, and application fields. This structured analysis provides the empirical basis for the conceptual model and indicator system proposed by this study.

It is important to reiterate that this article is not based on original empirical data but constitutes a conceptual contribution grounded in a scoping review. Its goal is to inform future research and practice in participatory urban governance by offering an operational model of subjective indicators usable in PPGIS environments.

The review, however, is predominantly informed by literature focused on the Global North, especially Europe, North America, and Australia. While this bias reflects existing publication patterns in high-indexed databases, we acknowledge that contextual adaptations may be necessary to apply the model in Latin American, African, or Asian cities. Thus, the framework should be understood as a flexible structure, open to redefinition in culturally diverse urban contexts.

4. Results: frameworks and indicators to assess urban perception through PPGIS

Some of the articles associated with the development of PPGIS for the analysis of the urban environment and considered on these results are: the eCPAT application by Besenyi et al. (2016), designed to improve community parks with the input of young people; the PPGIS by Jelokhani-Niaraki et al. (2019) to assess the age-friendliness of Tehran (Iran); the Maptionnaire tool by Maarit Kahila and Anna Broberg, used by Kyttä et al. (2016) to measure perceived happiness associated with density and social sustainability in various neighborhoods of the Helsinki metropolitan area (Finland); and by Saadallah (2020) to spatialize the sense of community in Egypt; the SENSE tool by Chrisinger and King (2018) to measure stress experienced while walking through a neighborhood in San Francisco, California, USA; the Proctor Creek app by Osborne et al. (2018) to evaluate the environmental quality of urban wetlands; or the StEER tool by Kijewski-Correa et al. (2021) to assess the response of urban environments to natural hazards, among others.

The results include a systematization of the main theoretical and methodological frameworks identified across the reviewed studies, followed by a conceptual model developed from this analysis. This is accompanied by a description of the key indicators used to assess urban perception through Public Participation Geographic Information Systems (PPGIS), as well as an overview of the main recruitment strategies and study settings employed to explore citizens' perceptions. The detailed analytical process applied to each paper reviewed can be consulted in Supplementary File 1.

The results presented in Figs. 2–8 are based on a systematic coding of the 21 selected articles. Each indicator and category shown has been explicitly derived from the reviewed literature. The results section begins by systematizing the main theoretical and methodological frameworks identified across the selected studies. Based on this analysis, a conceptual model is proposed to structure the study of urban perception through Public Participation Geographic Information Systems (PPGIS). This is followed by a classification of key subjective and objective indicators used in the literature, as well as an overview of the most common recruitment strategies and application fields employed to capture citizens' perceptions.

4.1. Theoretical framework: public participation and the transactional person-environment approach

All the articles analyzed are theoretically grounded in the transactional person-environment approach or are associated with public participation arguments. Articles based on the transactional person-environment approach consider a dynamic and interactive relationship between the individual and the environment, where both the built environment and experiences are equally emphasized (Laatikainen et al., 2017). Furthermore, authors such as Brown and Kyttä (2014) and Laatikainen et al. (2017) have asserted that the transactional person-environment approach lays the foundation for participatory mapping in general and for Public Participation Geographic Information Systems (PPGIS) in particular, considering that participatory mapping relies on this ability of individuals to relate their perceptions to a particular place, attaching each person experiences with a specific physical and cultural context (Kyttä et al., 2013). To structure this approach, the person-environment transactional model is considered as a basis, establishing that each experience is defined by the physical context in which it occurs (Gibson, 1979; Samuelsson et al., 2018).

Additionally, public participation provides a political discourse framework by establishing the right for citizens to actively engage in decision-making processes, thereby enhancing community members' contributions to management processes associated with urban planning and urban life (Szarek-Iwaniuk & Senetra, 2020). Generally, citizen participation has been linked with processes that entail the direct involvement of individuals in decision-making, incorporating local knowledge and integrating spatial information from the user's perspective (Saadallah, 2020). This includes mechanisms such as legislative initiatives, referendums, plebiscites, public consultations, or the integration of citizen councils for the design of public policies. In recent decades, the emergence of networked societies has led to the development of new communication platforms. These platforms have empowered the role of citizens and, consequently, have improved bottom-up planning processes in the urban environment (Liu et al., 2017; Saadallah, 2020). Several articles utilizing Public Participation Geographic Information Systems (PPGIS) have supported their theories on public participation processes. In this context, Szarek-Iwaniuk (2020) emphasizes the importance of electronic public participation as part of the smart cities movement, enabling governments to reach more people than traditional citizen participation methods, while simultaneously facilitating active citizen engagement in the consultation process through digital platforms.

4.2. Methodological framework: participatory mapping and citizen science

The methodological support underpinning the collection of data related to urban perception is recognized in two frameworks, which may well be complementary. On one hand, there is an approach that seeks to 'spatialize' citizen perception through participatory mapping linked to the transactional person-environment approach. On the other hand, there is a framework recognizing citizens as experts in their environment, empowering them to collect analytical data, recorded as citizen science.

From the perspectives of environmental psychology and the person-environment approach, participatory mapping focuses on locating individuals' experiences and/or preferences on a map, allowing them to be studied in a context-sensitive manner (Kyttä et al., 2016; Saadallah, 2020), thereby facilitating the analysis of the relationship between the physical environment and each individual's preferences (Laatikainen et al., 2017). In recent decades, the study of urban perception through participatory mapping has surged due to the emergence of digital platforms that have redefined traditional participatory mapping practices through Geographic Information Systems (GIS) (MacKerron & Mourato, 2013; Zeile et al., 2015). The use of these two tools together has been shown to increase the representativeness of different sociodemographic groups in participatory processes (Kahila-Tani et al., 2019), validating the diversity of impressions by focusing on gathering a wide range of opinions within the local context (Brown & Kyttä, 2014), and facilitating access for a larger number of participants in the citizen consultation process (Saadallah, 2020).

On the other hand, the term Citizen Science is associated with the

Fig. 2. Socio-environmental indicators.

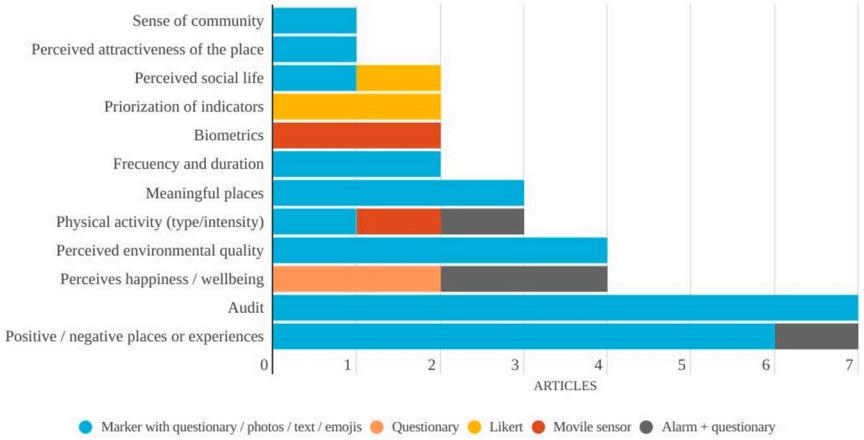

Fig. 3. Subjective indicators to study perceived environments.

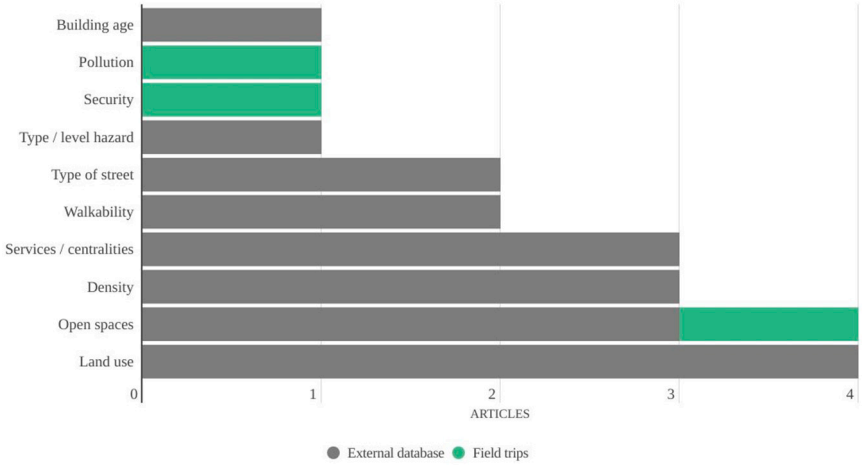

Fig. 4. Objective indicators to assess urban environment from spot location.

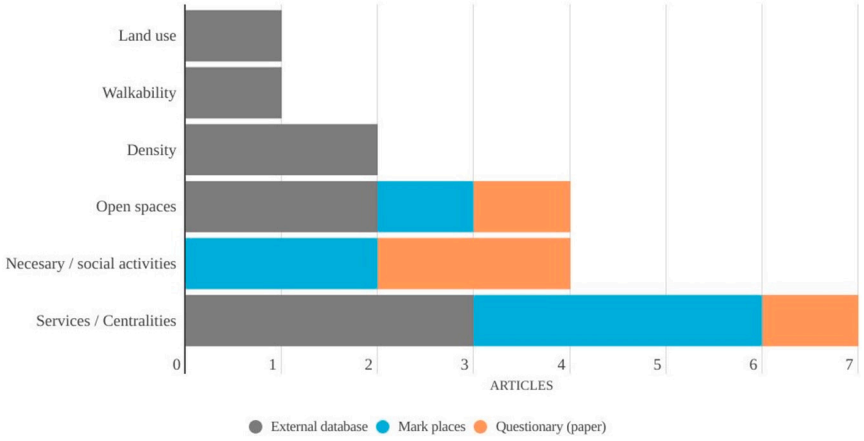

Fig. 5. Objective indicators to assess urban environment from home location.

recognition of citizens' expertise in their local domains and is considered a fundamental component of the Citizen as Sensor paradigm (Resch, 2013). This term is often used to refer to a network of citizens acting as observers in various scientific fields (Goodchild, 2007). Citizen Science projects are linked to initiatives where measurements are provided by volunteer members of local communities, delivering evidence-based data to inform local action or decision-making processes (Haklay, 2013). Participatory sensing is considered a specific area within Citizen Science, relying on the use of smartphones equipped with internal sensors (such as GPS, cameras, microphones, or specific applications) to collect and share environmental measurements and citizens' daily experiences, thereby enhancing their knowledge of specific local areas (MacKerron & Mourato, 2013; Resch, 2013).

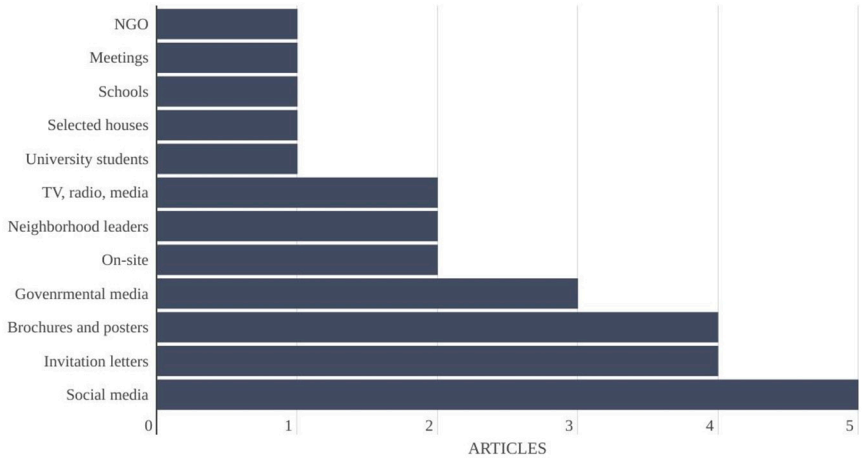

Fig. 6. Recruiting methods used in PPGIS.

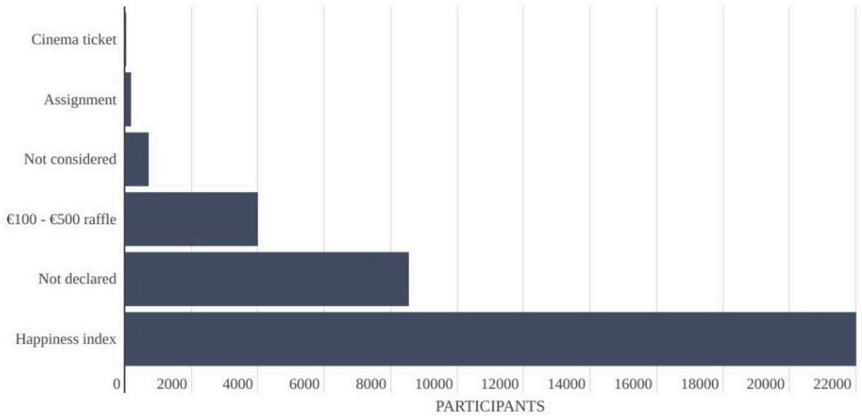

Fig. 7. Relation between incentives and participants.

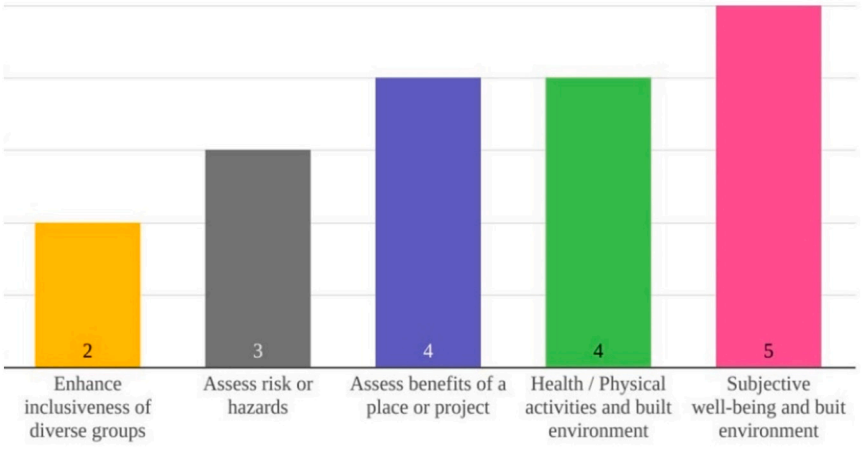

Fig. 8. Study fields assessing urban perception with PPGIS.

4.3. Application frameworks: subjective well-being, physical activity and audit tools

The analysis of the 21 selected articles has identified three application frameworks, two of them related with a subjective approach, and one of them associated with an objective approach (Brownson et al., 2009).

In the subjective approach:

- *Subjective well-being.*

Subjective well-being focuses on obtaining information about self-reported well-being (Chrisinger & King, 2018; Kyttä et al., 2016; Mcewan et al., 2019) or the happiness of the inhabitants (MacKerron & Mourato, 2013), contrasting these impressions with the characteristics of the urban structure evaluated through the use of external archival data using GIS.

- *Physical Activity and Urban Health.*

The framework for Urban Health states that the health of urban citizens is related to urban living conditions (Osborne et al., 2018). It is based on evaluating the type or level of physical activity (Fuller et al., 2021; Katapally et al., 2018) and/or the perceived environmental quality to perform physical activity (Besenyi et al., 2016; Kajosaari & Laatikainen, 2020; Rydenstam et al., 2021), studying its relationship with urban structure based on a set of external archival data. The result allows to relate relations between urban environment, physical activity and quality of life (Ojobo et al., 2024).

While in the objective approach:

- *Audit Tools.*

Are instruments and protocols used by researchers for studying the physical environmental conditions that are best assessed through direct observation at the community level (Brownson et al., 2009). These tools are based on protocols and criteria that guide the application of standardized instruments and forms, generally applied by personnel trained in the field (Remigio et al., 2019). Systematic observation (SSO) is the basic technical support used by the urban audit.

4.4. Conceptual model for studying urban perception through PPGIS

Perception is understood as the generation of impressions triggered by the environment (perceived environment) and conditioned by a set of personal circumstances (socio-environmental conditioning), such as physical, social and psychological factors (Kajosaari & Laatikainen, 2020; Lawson et al., 2022). Complementarily, in the urban context, the environment is interpreted as the sum of all those physical elements shaping the urban structure (Chrisinger & King, 2018; Haklay, 2013). These three general categories (1) socio-environmental conditions, (2) perceived environment, and (3) urban structure, configure the main aspects of the conceptual model to study urban perception through PPGIS (see Fig. 1).

This model considers that people's perception of their environments is related to the subjective approach (Brownson et al., 2009) based on the location of individual preferences over a map, and, therefore, corresponding to spatialized information. In contrast, the socio-environmental variables conditioning urban perception (Sabri et al., 2016) are evaluated using an objective approach, considering the sociodemographic factors of each participant such as age, sex, educational level or city of residence. These data characterize only the person, and not the context, therefore, corresponding to non-spatialized information. The context from which the perception arises is also studied through an objective approach based on archival data sets (GIS tools) or audit tools to evaluate the physical characteristics of the urban structure (Brownson et al., 2009). This data corresponds to spatialized or georeferenced information.

Unlike previous frameworks—such as Kyttä et al. (2016), which focused on studying social sustainability, by linking urban structural characteristics with accessibility and the experiential and outcomes, or Samuelsson et al. (2018), which follows similar principles correlating people experiences with the accessibility to different urban features. The model introduced here reorganizes these empirical insights into an operational and structure composed of three analytical domains that articulate subjective and objective data within a single framework. By consolidating rather than replicating previous approaches, it provides a transferable schema for identifying and spatializing indicators across diverse PPGIS applications, expanding their comparative and methodological potential.

In summary, the framework proposes that urban perception can be characterized and spatialized through the identification and location of personal impressions about the urban context (perceived environment), individualized through the sociodemographic particularities of each person (socioenvironmental conditioning), and contextualized in relationship to the physical characteristics where it occurs (urban structure), in a gradient that goes from the most subjective or perceptual to the most objective or material.

4.5. Subjective indicators for studying urban perception

The central scope of this article centers on operationalizing the conceptual model to assess citizen perception (Fig. 1) by identifying indicators for the analysis of each one of its categories (1) socio-environmental conditions, (2) perceived environment and (3) urban structure.

(1) **Socio-environmental conditions.**

Have been defined as those circumstances conditioning the perceived environment and are linked to objective indicators (such as age, educational level or city of residence), complemented with subjective indicators (such as health status or perceived quality of life). Sociodemographic factors strongly emerge as the main indicators considered to assess citizens' perception of their built environment (view Fig. 2). These mainly include age, level of education and gender, allowing perception to be related to the sociodemographic preferences of diverse groups of population, enabling to study the urban environment from an intersectional approach. Most of this data is obtained through non-spatialized questionnaires that are answered directly by the participant.

The second hierarchy of indicators to evaluate socio-environmental conditions is associated with perceived health or well-being, with data referring to health status, height/weight, or levels of general satisfaction with one's lifestyle. These data are obtained both through questionnaires and through the use of Likert or Slider scales (slider control). In the third hierarchy, indicators on personal experiences or values are recorded, such as physical activity carried out during adolescence, the use of public parks or cell phones, or the general perception of the community or neighborhood where one lives. These indicators are recorded entirety through questionnaires.

(2) **Perceived environment.**

It corresponds to the fundamental component in the measurements on urban perception, and all indicators are subjective in nature. Among the most recurrent indicators, the identification of positive/negative places or experiences stands out. They are followed by audit tools indicators. Both are mainly raised by locating a point in space and linking it with questionnaires, photographs, audios or emoticons to characterize it (view Fig. 3).

They are followed in recurrence by indicators associated with the evaluation of perceived well-being or happiness, as well as indicators to record the perception of the quality or benefits of the environment. Of this group, well-being indicators are recorded through questionnaires or random alarms that are activated on smartphones, while environmental quality indicators are recorded through spatialized markers associated with questionnaires. In a third hierarchy, indicators are focused on locate and characterize physical activities, as well as significant places for participants. Physical activity is defined by locating places on the map associated with questionnaires or narratives, and through reminders on smartphones or sensors on mobile devices. Significant places are recorded with markers and questionnaires or photographs.

(3) **Urban environment.**

The urban structure indicators are objective, logical and focus on characterizing the physical context where urban perception is recorded. In its analysis, a wide diversity of variables is observed, depending on the subject being studied. However, this scoping review has identified

two different approaches to study urban environment characteristics, either studying them around a specific place in the city prioritized by citizen preferences (1), or around the place of residence of each participant (2). These two approaches have been called around spot analysis and around home analysis.

Approaches to study urban environmental characteristics:

- *Around Spot.* This approach consists on selecting significant places around the city mapped by a diverse range of citizens, followed by a GIS analysis around these spots. This method is generally used to collect individual perception of common places, and its analysis is mainly related with the buffer-based method. The main indicators used to assess urban environment around these selected spots are: In the first hierarchy, land use, as well as location and accessibility to open spaces. In the second hierarchy, housing density or the relationship between residential and work density, accompanied by the location of commercial centralities or main social facilities (such as health, sports, cultural or educational centers). In the third hierarchy appears the evaluation regarding walkability accompanied by the type of street (Fig. 4).

- *Around Home.* This approach is based on analyzing urban environment characteristics around residential places of each participant. It is generally used to analyze individual behavior of citizens around their homes and neighborhoods. The main indicator used to analyze the location of significant places around the home is the location of centralities or social facilities. This indicator is collected, either by consulting external databases, asking the participant to locate these places on the map, or through citizen consultation questionnaires. In the second hierarchy, there are indicators on the location of daily or social activities, which are obtained through citizen consultation, or indicators on the location of open spaces, which are obtained through consultation of external data bases or are spatialized directly by the people who participate. in the study. Finally, there are indicators on housing density, walkability or mix of land use, which are obtained from external databases (Fig. 5).

The majority of articles related to the analysis of urban structure around the home adhere to the principles of social sustainability. This approach does not focus on studying a specific indicator, but rather on identifying accessibility patterns present in the urban structure (Samuelsson et al., 2018). The objective is to analyze the relationship between accessibility and urban experiences such as neighborhood attachment, social interactions, security, perception of urban environmental quality, housing satisfaction, stability, and participation in civic activities (Bramley, 2009; Kyttä et al., 2016). From this perspective, social sustainability offers a viewpoint where the ability to access significant daily places and services for participants conditions the quality of their everyday experiences (Laatikainen et al., 2018).

For analyzing urban structure accessibility in general, and social sustainability in particular, two methods have been identified. (1) Buffer analysis appears as the most commonly used method to assess accessibility to significant places, while (2) activity space emerges as the most precise method for analyzing citizens' mobility around their residences (Laatikainen et al., 2018).

Finally, a supplementary file has been created to map each article to the indicators it contributed to—categorized by socio-environmental, perceived, and structural dimensions.

4.6. Recruiting methods & rewards

Considering that digital platforms are mainly used by a specific segment of the population, it is important to identify the strategies adopted by different researchers to recruit a wider number of participants, looking for a better representation of a diversity of socioeconomic groups.

Regarding methods for recruiting participants in PPGIS, the reviewed case studies demonstrate a prevalence of social media as a dissemination strategy, followed by invitation letters, the use of brochures or informational posters, and coordination with local governments. Additional strategies include on-site recruitment, collaboration with community leaders, and the use of traditional media such as television or radio to disseminate and encourage public participation. Specific strategies were also identified for recruiting particular audiences, such as residents of selected housing near the study project, participation of minors through schools, attendance at neighborhood meetings, or collaboration with NGOs (view Fig. 6).

From the reviewed cases, the average of participants is 2516. The intersection between recruitment methods, the type of "reward" or incentive offered, and the number of participants involved in the study reveals that the most efficient methods for attracting users or informants are associated with rewards offered to participants, whether in the form of cash prizes through raffles or personalized information that will be useful to the user. In general, raffle between participants is the most recurrent tactic. Although the Mappiness app (MacKerron & Mourato, 2013), got 22,000 users by offering participants the opportunity to evaluate their happiness level via a mobile application (view Fig. 7). It is also pertinent to highlight this was the only case studied which appeared on TV and radio broadcasting, while being highlighted in the App Store for two weeks after being launched. The average of participants of the cases studied, without considering Mappiness, is 1016 participants.

4.7. Relation between study fields and subjective indicators

The analysis of the 21 articles resulting from the scoping review has allowed for the classification of recent studies on urban perception using PPGIS into five main fields. These are, in order of prevalence: (1) the study of perceived well-being in relation to urban environment characteristics, (2) the study of health and physical activity in connection with the urban environment, (3) the assessment of benefits or contributions of a specific urban place or project according to users' perceptions, (4) the evaluation of risks or disasters impacting the urban environment, and lastly, (5) the field focused on facilitating the inclusion of diverse groups in the enjoyment of public and open spaces in the city (view Fig. 8).

The indicators used for studies on subjective well-being (Chrisinger & King, 2018; Kyttä et al., 2016; MacKerron & Mourato, 2013; Saadallah, 2020; Wannemacher et al., 2018) align with the primary majorities identified in the scoping review: sociodemographic data, location of positive/negative places, land uses around the area, and centralities or amenities around the home. Audit studies, as well as analyses around the location and the home, are identified.

In studies on health and physical activity (Kajosaari & Laatikainen, 2020; Katapally et al., 2018; Mcewan et al., 2019; Rydenstam et al., 2020), sociodemographic data is complemented with perceived health backgrounds. The main indicator of the perceived environment is the type and intensity of physical activity, and no specific indicator shows prevalence for the analysis of the urban structure, although the location of sports facilities and characterization of open spaces are among the most notable. Studies with place-based, home-based analyses and citizen audit approaches are also recognized.

Of the four articles focused on evaluating the benefits of a place or project (Besenyi et al., 2016; Fuller et al., 2021; Jose et al., 2015; Orru, 2015), two use the urban audit approach. The most recurrent socio-environmental characteristic indicator is sociodemographic data. There is no prevalence of indicators in any other domain, though there is a noted complementarity between the location of positive/negative places and environmental benefits or perceived well-being.

In risk assessment (Kijewski-Correa et al., 2021; Osborne et al., 2018; Remigio et al., 2019), all studies are urban audits, operating by recording data from a specific city location. Generally, environmental conditions are not considered, and the main audit indicator is the

location of the type and intensity of disaster in the urban environment.

Finally, studies focused on facilitating the inclusion of diverse groups in the city (Jelokhani-Niaraki et al., 2019; Laatikainen et al., 2017) agree on recording the sociodemographic profile of participants, as well as collecting perceived environment indicators linking place preference with environment perception (e.g., positive places with social life and attractiveness of the place). There is a recognized consistency in selecting indicators on the urban structure, identifying open spaces, centralities, and/or amenities, as well as indicators associated with walkability.

It is important to note that although the total number of studies included in the scoping review is 21, only 18 articles are represented in Fig. 8. This is because three of the reviewed works are conceptual in nature or do not apply subjective indicators within a specific empirical field. Consequently, these articles were not classified under the five applied domains presented in this figure, which focuses exclusively on empirical applications of PPGIS in the assessment of urban perception.

5. Discussions

This article set out to address a research gap in the field of urban studies by identifying subjective indicators for assessing urban perception through Public Participation Geographic Information Systems (PPGIS). While existing research has addressed the technical and participatory dimensions of PPGIS (Brown & Kyttä, 2014; Kahila-Tani et al., 2019), fewer studies have focused on developing conceptual models capable of systematically integrating subjective and objective data in participatory spatial analysis (Anonymous, 2022). This article contributes to this gap by proposing a conceptual framework grounded in a scoping review of 21 studies, offering a structured approach to operationalize subjective indicators of urban perception.

The findings reinforce the need to advance in theoretical debates about the limitations of objectivist planning paradigms. Conventional urban analysis tends to privilege measurable, aggregated, and "neutral" data —such as income levels, access to infrastructure, or land-use zoning— while neglecting the affective, experiential, and symbolic dimensions of space (Gavrilidis et al., 2016; Mouratidis, 2021; Nenko & Petrova, 2018; Zeile et al., 2015). This technocratic rationality, while valuable for comparative diagnostics, obscures the micro-geographies of preferences and inequality perceived by residents in their everyday life (Pérez Sanz & Gregorio Gil, 2020; Arias & Muxí, 2018). The integration of subjective indicators into urban analysis thus emerges as an epistemological shift: it challenges the idea of a single, measurable urban reality and instead acknowledges the coexistence of multiple, situated urban experiences. As several scholars have argued, planning for spatial justice requires more than redistributive policies — it demands recognition of differentiated needs and the legitimacy of experiential knowledge (Bailly, 1979; Jacobs, 1967; Mouratidis, 2021; Pérez Sanz & Gregorio Gil, 2020).

The conceptual model proposed in this article is built from the theoretical and methodological foundations identified in the reviewed literature. It articulates three analytical domains socioenvironmental conditionings, perceived environment, and urban environment—that reflect the person–environment transactional perspective (Gibson, 1979; Kyttä et al., 2013; Samuelsson et al., 2018; Van Kamp et al., 2003). Rather than advancing a new theory, the contribution lies in articulating a common analytical structure drawn from interdisciplinary literature, capable of guiding future empirical research using PPGIS tools. By bridging elements from perceptual geography (Downs & Stea, 1973; Vara, 2008), environmental psychology (Roth, 2000; Zube, 1999; Marques et al., 2020), and neo-geography (Goodchild, 2007; Resch, 2013), the model offers an interdisciplinary synthesis, providing a platform for both conceptual advancement and practical implementation.

Among the most salient findings of the review is the recognition of subjective indicators such as emotional attachment to place (positive/negative places or experiences), followed by perceived environmental quality and well-being. These indicators are increasingly used to assess spatial experiences and latent socio-environmental inequalities that may not be captured by conventional urban metrics (Gavrilidis et al., 2016; Nenko & Petrova, 2018; Zeile et al., 2015). Particularly relevant are indicators of perceived health and psychological well-being, which emerged frequently in studies that aimed to spatialize intangible aspects of urban life (Chrisinger & King, 2018; Kyttä et al., 2016; Laatikainen et al., 2017; MacKerron & Mourato, 2013; Mcewan et al., 2019; Samuelsson et al., 2018). These indicators not only reflect individual-level experience but can also signal deeper socio-environmental stressors, such as fear of crime or disconnection from green infrastructure. They are especially valuable for diagnosing population needs analyzed intersectionally (Crenshaw, 1989), providing insight into differentiated urban experiences and disparities in quality of life. The inclusion of subjective indicators in urban diagnostic is essential to informed planning interventions aligned with citizens' real and felt needs.

However, it is important to clarify that the set of indicators proposed in this article is not prescriptive but heuristic. It offers a flexible entry point for the assessment of urban perception, which must be adapted to local contexts (whether in the Global North or South), scales of analysis (metropolitan, neighborhood, street, or project scale), and future methodological advances. For instance, the growing use of machine learning models in participatory platforms may enable the dynamic updating of indicators, or even the emergence of new ones based on user-generated data patterns (Bose et al., 2023; Gavrilidis et al., 2016; Jelokhani-Niaraki et al., 2019; Marti et al., 2019; Peng et al., 2021; Roy et al., 2024). The list of indicators is thus best understood as an evolving catalogue, whose value lies in its ability to structure perception data rather than dictate what should be measured. Therefore, the hierarchy of these indicators raises important questions. While this structure seeks to organize a highly heterogeneous literature, it does not presume a universal or static hierarchy. Privileging, for instance, indicators favored by health sciences or produced in Global North contexts could reproduce epistemic asymmetries and reinforce dominant paradigms (Cardullo & Kitchin, 2019). In this regard, the set of indicators advocates for a reflexive stance, encouraging adaptation through participatory co-design, contextual validation, and the inclusion of culturally grounded variables.

What remains relatively standardized — and may be considered the most transferable contribution of this study — is the model itself. When implemented through PPGIS platforms, the model enables two core operations that are both technically feasible and epistemologically robust: (1) the spatialization of urban perception through the geolocation of subjective indicators, and (2) its systematic linkage with the sociodemographic profile of each respondent. This structure builds the bases for an intersectional analysis, as it enables not only the location of citizen experience but also the identification of preferences and needs across different social groups—categorized by gender, age, income, ethnicity, etc.—and therefore potentially prioritizing those historically marginalized in planning processes.

This dual emphasis on geolocation and demographic tagging—allows for context-sensitive comparisons without requiring changes to the model's underlying logic. In this sense, although the current scoping review primarily reflects literature from the Global North due to the structure of high-index academic publishing, we argue that the model remains replicable in cities of the Global South. Its simplicity, grounded in the transactional person–environment approach (Gibson, 1979; Kyttä et al., 2013; Samuelsson et al., 2018; Van Kamp et al., 2003), is precisely what enables its adaptability. The dominance of Global North contexts, however, reveals broader epistemic asymmetries in urban knowledge production, where access to digital infrastructure, data availability, and institutional capacities favor research in well-resourced regions. Recognizing this imbalance is crucial, as it shapes both the methodological development of PPGIS and the type of indicators prioritized in the literature. Yet, this limitation also highlights

an opportunity: by applying the model in Global South contexts through participatory co-design and culturally grounded validation, future studies can diversify existing frameworks and contribute to a more plural geography of urban perception. By centering the role of lived experience and enabling its spatial and demographic contextualization, the model provides a structured yet open-ended tool for operationalizing perception in planning—one that supports both comparability and cultural specificity.

The implications of this research for urban planning and governance are both methodological and political. On one hand, the model provides a replicable framework for integrating experiential data into planning platforms, potentially strengthening citizen engagement and the responsiveness of urban policies. On the other hand, it calls for a rethinking of evidence in planning: moving beyond technocratic indicators and incorporating plural forms of knowledge and affective relationships to space (Mouratidis, 2021; Nenko & Petrova, 2018; Pérez Sanz & Gregorio Gil, 2020; Zeile et al., 2015). From a practical perspective, this model offers urban planners and decision-makers a structured tool to incorporate perception-based data into diagnostic and investment processes. Its application can support the identification of spatial inequalities, guide the prioritization of urban interventions, and inform the design of inclusive public policies grounded in citizens' lived experiences. Moreover, by embedding these subjective indicators into GIS-based planning systems, local governments can enhance transparency, evaluate policy impacts over time, and promote more equitable, data-informed urban governance.

Future research should focus on testing the model in empirical case studies, developing machine learning applications for perception analysis, and exploring advanced analytical approaches—such as geographically weighted regression (GWR), multiscale GWR (MGWR), spatial autocorrelation methods like Moran Global I and LISA (Local Indicators of Spatial Association), or modelling techniques such as structural equation modelling (SEM) and importance–performance analysis (IPA)—to better understand the relationships between spatialized objective indicators and citizens' perceptions collected through PPGIS. Ultimately, this work contributes to reimagining the role of public perception as a cornerstone of democratic urbanism.

6. Conclusions

This study has aimed to develop a conceptual framework for assessing urban perception through subjective indicators collected via Public Participation Geographic Information Systems (PPGIS). By systematizing existing literature, it identified key indicators and their relation to sociodemographic profiles and urban structure, offering a model capable of geolocating person-environment experiences. The findings reaffirm that subjective indicators—despite their apparent simplicity—hold complex analytical potential when examined in contrast to spatial configurations and demographic data. These indicators open new possibilities for understanding how different social groups perceive, inhabit, and are affected by urban spaces.

As smartphones and digital tools become increasingly integrated in everyday life, a new paradigm has emerged—one where citizens contribute data not passively, but as active sensors within the built environments. Yet, the sense of empowerment often promised by smart city rhetoric invites more critical consideration. While PPGIS platforms can indeed democratize the collection of experiential knowledge, their deployment does not automatically guarantee that this knowledge will influence decision-making. Empowerment requires not only technological access, but also institutional mechanisms that legitimize and act upon the data produced by citizens. Without such mechanisms, there is a risk that participatory mapping becomes an extractive process—harvesting data from communities without redistributing influence or voice.

However, while technology continues to evolve, integrating subjective indicators into urban planning systems has the potential to transform governance practices. If properly institutionalized, these indicators could inform territorial diagnoses, prioritize public investments, and guide the design of inclusive urban policies. They could also support iterative planning processes that evolve with citizens' lived experiences, especially in rapidly changing urban contexts. The adoption of intersectional approaches and the use of digital platforms for real-time perception mapping may enable cities to become more responsive and reflective of their inhabitants' needs and desires.

By repositioning perception as a legitimate form of urban knowledge, this study contributes to a broader shift in urban studies—one that challenges objectivist traditions and underscores the importance of lived experience as a driver of spatial justice and inclusive governance.

Future research could expand this work by increasing the sample of analyzed cases, refining indicator typologies, and exploring new analytical intersections between subjective data and urban structure.

CRediT authorship contribution statement

Montserrat Delpino-Chamy: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yolanda Pérez Albert:** Supervision, Project administration, Methodology, Data curation, 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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2026.106809.

Data availability

Data will be made available on request.

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