Research Paper

The Factors and Indicators System That Influences Sustainable Density

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Abstract

In the urban planning, the evolution and prospects of density research indicate that density serves not only as a measure of urban physical form but also as a crucial tool for addressing urban challenges, managing urban morphology, and regulating the relationship between humans and their environment. With the rapid global population growth, achieving high quality and sustainable development in high-density urban settings has emerged as a significant issue in urban planning theory and practice. This paper introduces the elements of sustainability and the definition of density, categorizing streets based on their functions into commercial spaces, office spaces, residential spaces, and public spaces. Building on this functional classification, it investigate key density indicators relevant to each category. Ultimately, a model is established to illustrate the relationships among various density concepts, thereby creating a density framework. This framework can facilitate changes in urban density, promoting sustainability and enabling urban transformation.

Keywords

sustainability, density, floor area ratio, residential, commercial, office, public space

1. Introduction

The study of urban sustainable density primarily requires an examination of two aspects: urban sustainability and urban density. Urban density encompasses a variety of definitions; however, a comprehensive model that illustrates the interconnections of urban density has yet to emerge. This paper aims to construct a model at the neighborhood scale that elucidates these relationships, based on a clarification of several definitions of urban density. Initially, the paper categorizes urban functions at the neighborhood level into residential, commercial, office, public space, and other functions, and investigates the density relationships among these functional zones. Building upon this foundation, population density is incorporated to jointly establish a model that represents both urban density and population density. Finally, recommendations for the development of the urban density model are presented.

2. Definition

2.1. The definition of sustainability

Different scholars have varying definitions of sustainable development, a concept that can be traced back to the early 1970s when various studies warned of the need to impose limits on Western development models. Subsequently, the concept emphasized that sustainability is a normative concept that indicates how humanity should interact with nature and how we should be accountable to one another and future generations (Baumgärtner and Quaas, 2010)(Baumgärtner, 2010). The concept highlighted that the essence of sustainable development lies in meeting fundamental human needs while safeguarding the Earth's life-support systems. The concept of sustainable development has become a reference for scientific research on the environment and has acquired a paradigm character for development(Alvarado-Herrera et al., 2017). The concept also been used in issues related to agricultural production (Gouda et al., 2018; Lathuillièreetal., 2018) business(Amranet al., 2015; Dangelico and Pontrandolfo, 2015), industry (Lambert and Boons, 2002), circular economy (Suárez-Eiroaetal., 2019) and has become the conceptual foundation of theoretical approaches like green economy (Bina, 2013). As Mitlin(Mitlin, 1992) noted, the legacy that associates the concept of sustainable development with economic growth has sparked debates over its contradictory interpretations. This is because various scholars hold divergent views on the relationship. Some contend that development, when equated with economic growth, is at odds with sustainability, given that an infinite growth trajectory on a finite planet is inherently unfeasible (Beckerman, 1992).

Several key indicators of sustainable cities include: Sustainable Transportation: "Reflects the comprehensive social and environmental costs of the transportation services provided; respects carrying capacity; and balances mobility and safety demands with accessibility, environmental quality, and community livability needs." Density is defined as the ratio of residential units or people to a designated land area, a crucial element in the discourse on sustainable urban form. Mixed Land Use: Planners and scholars widely agree that Mixed land use is essential for promoting sustainable urban development(Daly, 2006; Spangenberg, 2002). Diversity: The diversity of activities is a key factor in achieving urban sustainability and fostering other desirable urban characteristics (Folke, 2006). Greening: Also known as green urbanism, greening has emerged as an important design concept for sustainable urban form since the 1990s (Luke, 2005).

2.2. The definition of density

The earliest definition of density originates from physics, indicating the mass per unit volume. Subsequently, the concept of density has been expanded into various fields, resulting in a multitude of definitions (Fig.1). For instance, spatial density, social density, and perceptual density, among others. In urban planning, density serves as a crucial metric for assessing urban density, primarily encompassing density indicators that influence the built environment, including Floor Area Ratio (FAR), plot density, street density, total residential density, overall site density, residential density, neighborhood density, and total living area density. Additionally, it includes density indicators beyond the built environment, such as population density. The Floor Area Ratio (FAR) is a key metric in urban planning used to evaluate building density and land use, representing the ratio of total building area to the area of land occupied by the building. Population density (POP) refers to the number of residents living within a unit area, which is a critical factor in the evaluation of residential density. However, the limitations of the population density metric lie in its inability to inform us whether each individual has adequate (or comfortable) living space, whether the size of residential units is reasonable, the condition of public spaces, and how many individuals reside within each living unit.

The comprehensive definitions of sustainability and density highlight that the essence of sustainable density lies in achieving an appropriate balance that fosters community vitality while enhancing the accessibility of services and facilities, without leading to excessive congestion, deteriorating living conditions, or adversely affecting the urban microclimate. For instance, excessively high density may result in increased stress for residents and a decline in the quality of the living environment, whereas excessively low density can lead to urban sprawl and inefficient resource utilization. Sustainable density, influenced by both population density and building density, refers to the average number of residents, buildings, or housing units per unit of land area within an urban area or specific zone, provided that the quality of life for residents and the sustainability of the urban environment are maintained. In urban planning, sustainable density plays a crucial role as it is directly linked to the goals of sustainable urban development. Therefore, relevant indicators concerning population density and building density, as mentioned in the EU SDG Indicator set 2020 from the 2019 SDG Index and Dashboards Report for European Cities (prototype version), can be utilized to establish a sustainable model of urban density. This model can serve as a framework for small-scale sustainable urban density, while also allowing for the exploration of additional factors influencing sustainable density at a larger scale to develop a comprehensive urban density model.

3. Methodology

Based on the identification of sustainable development factors, a comprehensive understanding of the diversity of urban density at the street level is established, encompassing building volume, floor area, housing, population, employment, as well as measured and perceived density. This approach seeks to explore the interconnections between various density measurement indicators within the context of sustainable development. For instance, it examines the relationships among indicators such as urban building density, super-tall building density, and regional development intensity within the framework of building density. Furthermore, it incorporates sustainable indicators mentioned in the 2019 SDG Index and Dashboards Report for European Cities (prototype version) EU SDG Indicator set 2020 classification. These include metrics related to population density, such as the coverage rate of housing security services for the resident population (%), and resident population density; as well as metrics concerning public space density, including satisfaction with cultural facilities (%), the number of sights and landmarks (per 100,000), museum coverage (per 100,000), and concert and show coverage (per 100,000). This leads to the establishment of a sustainable indicator model built upon traditional indicator frameworks. Consequently, it integrates measurement models of buildings, population, and other factors, linking them to issues of scale and urban intensity. Thus, a comprehensive approach is proposed, connecting key concepts within a defined theoretical framework.

4. Classification of indicators

Cities are composed of various streets, and studying urban density can be approached through the lens of street units. This is due to the diverse nature of street density, which encompasses residential, commercial, office, public spaces, and a variety of other uses.

The indicators of residential spaces within urban streets primarily encompass apartments, detached villas, semi-detached villas, townhouses, low-rise multi-family residences, and affordable housing's floor area ratio, along with the building heights specific to the designated study area. These indicators are regulated by both the floor area ratio and building height. This relationship, however, has exceptions, as not all built areas are above ground, nor do all structures possess clearly defined footprints and vertical walls. Nonetheless, this correlation is prevalent in a significant proportion of buildings across most cities. Structures that are inclined or span over ground spaces still adhere to the same general principles. The diagram illustrates that density is regulated by building height, but it does not originate from it; building height is not a reliable predictor of total built area, as it is contingent upon the footprint and floor area ratio.

The indicators of commercial spaces within the streets primarily include the land use mix on both sides of the street, storefront density, transparency, the percentage of gray space, and signage density. Specifically, (1) the land use mix on both sides of the street refers to the fact that commercial mixed-use streets with urban traffic functions typically do not consist solely of commercial functions; they often include mixed residential and commercial land uses, as well as mixed office and commercial uses. Therefore, the foot traffic attracted to these commercial mixed-use areas includes not only local residents but also visitors and office workers; (2) storefront density is defined as the number of commercial unit entrances per 100 meters along each street segment, calculated using the formula: storefront density = total number of storefronts / length of the street segment × 100%. This includes: ① fully open storefronts, where the interior layout is directly visible; ② storefronts with transparent glass windows allowing visibility into the interior; ③ storefronts with advertising-style glass windows showcasing product displays; ④ storefronts obscured by opaque walls or flat advertisements. The formula for transparency is as follows: transparency = (length of type ① interfaces × 1.25 + length of type ② interfaces + length of type ③ interfaces × 0.75) / total length of the building interface along the street segment. The percentage of gray space refers to the ratio of the area of building overhangs or second floors extending over the street to the total street area per 100 meters of each segment. The formula is: gray space percentage = area of overhead buildings within the segment / total area of the segment × 100%. (3) Signage density reflects the volume of advertisements from businesses along the street, indicating the extent to which businesses provide information about their products to pedestrians. The density of street signage is defined as the ratio of the number of signs per 100 meters to the length of the street.

The metrics for office spaces within urban environments can be categorized into various types, including business office spaces, open-plan offices, semi-open offices, and unit offices. The indicators for office spaces are analogous to those for residential spaces, primarily relying on the floor area ratio and the height requirements of the office area for regulation. However, it is important to note that office buildings often consist predominantly of business-oriented structures, which are composed of one or more types of office spaces.

The indicators for public spaces within streets primarily include the open space ratio, which refers to the proportion of total open space to total built area, without distinguishing between private and public spaces. In addition to the open space ratio, public space indicators also encompass metrics such as the satisfaction rate of cultural facilities as outlined in the 2019 SDG Index and Dashboards Report for European Cities (prototype version) and the EU SDG Indicator set 2020. These metrics include the ratio of landmarks, surface area, museums, concerts, exhibitions, historical preservation buildings, and the coverage of accessible facilities in public spaces. In the context of public space indicators, The populations of "visitors," "residents," and "workers" cannot be aggregated for determining the overall population, as several local visitors serve as substitutes for residents and workers who would otherwise occupy various areas. This is shaped by the urban dynamics of production, consumption, entertainment, leisure, and mobility. The assessment of "visitors" merely indicates the distinction between local and global movements. The ratio of visitors will fluctuate according to functional makeup, employment rates, and industry categories; for instance, in dormitory suburbs, industrial districts, and tourist locales, the visitor count may be less than or beyond the number of absent residents and employees. As a result, we establish a definitive statistic termed street life density.

5. The process and content of model development

First, taking mixed-use streets as an example, I will analyze the components that contribute to street density, which include residential areas, commercial spaces, office spaces, and public spaces. Public spaces can take various forms, such as landmarks, historical buildings, museums, concert venues, and exhibition halls. Each type of building corresponds to specific sustainability indicators, such as the cultural facility satisfaction ratio and landmark ratio found in the 2019 SDG Index and Dashboards Report for European Cities (prototype version) and the EU SDG Indicator set 2020. Additionally, commercial spaces are characterized by the land-use mix on both sides of the street, storefront density, transparency, percentage of gray space, and signage density. By integrating aspects of residential, commercial, office, and public spaces, I will collaboratively establish a density model. Furthermore, I will incorporate human density, as the density of people and buildings is inherently interconnected. Building upon this, I will create a model that combines street density and population density to effectively illustrate urban density.

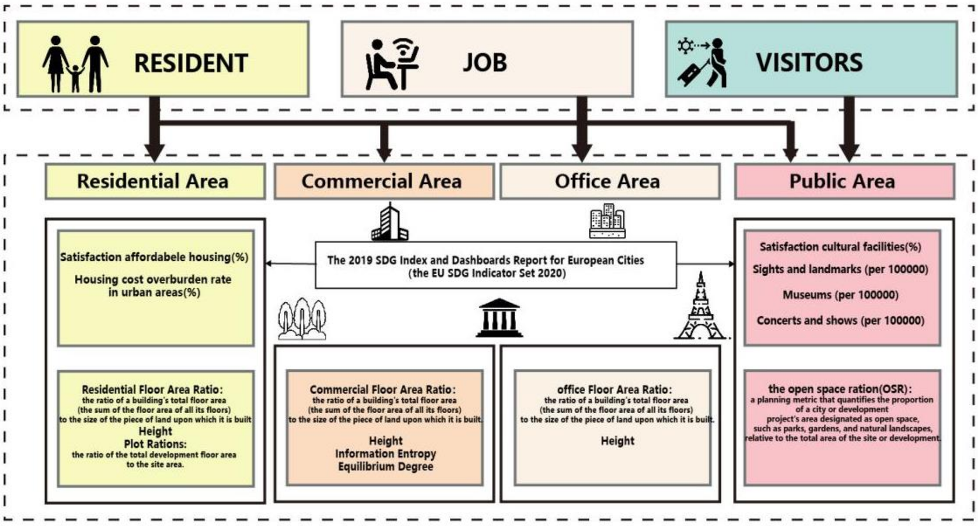

Fig. 1. Graphical representation of sustainable index model. Self-Illustrated by the Author.

This article establishes a framework for rethinking urban density. If density can be measured and interrelated in this manner, then urban density can be reinterpreted, allowing for transformations in cities through urban design and planning. Urban density plays a crucial role in urban sustainability for several reasons: efficient land use, reduced infrastructure costs, energy efficiency, the viability of public transportation, economic vitality, affordability, resource conservation, resilience, and equity.

In practice, various density control mechanisms have been developed based on these concepts, such as floor area ratio, building envelope, coverage ratio, and open space ratio. Despite the existence of such research and practice, creating a model that can capture the interactions between these diverse concepts and measurements has proven to be challenging. Urban density is not merely an attribute of buildings or individuals, but rather the spatial relationships between them; between buildings, between people, and between people and buildings. This paper presents a comprehensive approach to conceptualizing urban density, aimed at clarifying and connecting key concepts within a broader combinatorial theoretical framework. The model integrates residential space indicators, commercial space indicators, office space indicators, and public space indicators within the streets, collectively forming a comprehensive mixed-use indicator model. In the future, this model can be widely applied to enhance the sustainability of urban density by demonstrating the relationships between densities and exploring the connections between sustainability indicators.

The indicators of residential spaces within urban streets primarily encompass apartments, detached villas, semi-detached villas, townhouses, low-rise multi-family residences, and affordable housing's floor area ratio, along with the building heights specific to the designated study area. These indicators are regulated by both the floor area ratio and building height. This relationship, however, has exceptions, as not all built areas are above ground, nor do all structures possess clearly defined footprints and vertical walls. Nonetheless, this correlation is prevalent in a significant proportion of buildings across most cities.

6. References

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