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BIBLIOMETRIC ANALYSIS OF RESEARCH ON URBAN RESILIENCE: TOWARDS A SYSTEMATIC FRAMEWORK

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A b s t r a c t

Amid increasing challenges associated with urbanisation and climate change, urban resilience has become a central focus in scientific research. The rapid evolution of this field has resulted in fragmented theoretical perspectives, which hinder a comprehensive interpretation of current studies. This study aims to identify the principal dimensions of urban resilience and to systematise them through bibliometric analysis. The identified research gap is the absence of a coherent conceptual framework that integrates contemporary trends in urban resilience research. The study introduces an original conceptual framework comprising five dimensions of urban resilience and an overarching dimension of disruption that integrates the remaining components. The methodology includes a literature review and bibliometric analysis of works published between 2010 and 2025 and indexed in the Scopus database, utilising keyword co-occurrence analysis in VOSviewer. The findings reveal that recent research predominantly addresses administrative-managerial and infrastructural-spatial dimensions, whereas environmental, economic, and social dimensions are comparatively underrepresented. This study consolidates the existing body of research on urban resilience. It presents a conceptual framework for green urban resilience, which may serve as a basis for future investigations into the development of the urban resilience concept.

Keywords: green urban resilience, environment, dimensions, city, urban planning, climate change

1. INTRODUCTION

Contemporary cities face growing social, economic, and governance challenges in a multi-crisis environment marked by intense urbanisation, demographic pressures, social inequalities, and the ongoing climate crisis. These phenomena deepen tensions in urban systems, weakening their ability to ensure a high quality of life for residents and maintain stable development. The accumulation of social and economic problems often coexists with environmental challenges, increasing cities' vulnerability to various crises.

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In the context of ongoing civilizational development, cities should be viewed as complex, dynamic, and nonlinear systems in which interconnections among the social, economic, spatial, and environmental spheres determine their functioning [8], [91]. In the chaos theory approach, even small disruptions can lead to disproportionately large changes in the city's structure and organisation [67], making development difficult to predict. Consequently, cities experience both short-term disruptions and long-term transformations. Floods illustrate such disruptions, affecting an entire spatial unit while generating economic, infrastructural, spatial, and social problems [90]. Their effects are not limited to the material dimension; they also affect residents' psychological well-being. In response, residents develop adaptive mechanisms such as selective attention or social withdrawal, which can limit their capacity to respond to everyday disruptions [113].

From the ecosystem approach, a city functions as a system of interconnected elements encompassing society, infrastructure, and the natural environment [109]. Disturbances in one component can therefore unbalance the whole system. For example, increasing urbanisation at the expense of green spaces or air pollution negatively impacts living conditions, intensifying urban heat islands [25]. In this context, green areas constitute a crucial component of the city's structure, determining quality of life and environmental stability [95].

The concept of urban resilience [106], [14], [71] responds to the growing complexity and vulnerability of cities to various crises. UN-Habitat [46] defines it as the ability of an urban system to maintain operational continuity in the face of shocks and stresses. A key element of resilience is not only the ability to withstand disruptions but also to adapt and transform towards more sustainable development [41]. The literature emphasises that resilience remains closely linked to sustainable development, highlighting urban systems' ability to learn and adapt [2], [77]. While sustainable development focuses on balancing environmental, social, and economic dimensions, urban resilience emphasises the capacity to absorb disruptions and maintain key functions during crises [92].

From this perspective, cities' ability to respond to shocks (sudden events such as floods, fires, or hurricanes) and stresses (long-term processes such as climate change or demographic pressure) is particularly important, as is the time available for the urban system to undertake effective adaptation measures. The speed and effectiveness of the urban organism's response to disruptions largely determine its resilience and capacity for further development [118].

2. URBAN RESILIENCE: THEORETICAL PERSPECTIVE

The concept of urban resilience dates back to the 19th century. According to Masik [69], the first definition of resilience appeared in the Encyclopaedia Britannica and referred to the physical property of a body that is deformed by compressive forces to regain its size, i.e., return to its original state [85]. Currently, many different definitions of urban resilience can be found in the literature [78], [81]. The concept of urban resilience has evolved alongside research on the impact of negative stimuli on the condition and behaviour of urban centres. In his groundbreaking work, Holling [50] first introduced the concept of ecological resilience, defining it as the ability of a system to absorb disturbances and reorganise without losing its ability to function. Building on this, the adaptive cycle proposed by Holling et al. [51] describes the dynamics of change in complex systems, including cities, through four successive phases: exploration, consolidation, destruction, and renewal. The exploration phase represents a period of dynamic growth and the search for new development paths with high system flexibility. The consolidation phase is a period of structural stabilisation, accompanied by a decline in adaptive capacity. The destruction phase involves the sudden collapse of the existing order and the loss of some resources as a result of the crisis. The renewal phase involves the reorganisation of the system and the creation of new development structures. In this approach, the process of transitioning between

phases is sometimes interpreted as analogous to the phenomena of degradation and reactivation of urban areas (e.g., in the context of revitalisation), although it does not mean a simple return to a previous state, but rather its transformation [68].

The Resilience Alliance, an international, multidisciplinary research organisation founded in 1999 that studies the dynamics of social-ecological systems, adopts an understanding of urban resilience similar to Holling's. According to the Resilience Alliance [94], urban resilience refers to the capacity to cope with emerging adverse phenomena by adapting to existing conditions. This definition is supplemented by Ahern [2], who emphasises that resilience is a process of continuous learning and adaptation to changing conditions. In the context of resilience, the Intergovernmental Panel on Climate Change [53] further highlights an important aspect of adaptation to climate change: cities should reduce their vulnerability to adverse impacts and increase their capacity to recover quickly.

A different approach to urban resilience is presented by Leichenko [63] and Chelleri [18], who emphasise the importance of appropriate governance for urban resilience. Leichenko [60] points out that urban resilience focuses on the ability of cities to manage risks amid uncertainty and adapt to threats originating from the natural environment as well as those generated by human activity. By contrast, Chelleri [18] does not focus his definition specifically on risk management but indicates that urban resilience is a comprehensive approach to urban management that should take into account the ability to withstand challenges across various temporal and spatial scenarios.

One way to understand a city is through a holistic approach, considering it as a complex system in which all its elements and processes are interconnected [121]. In this approach, the city is analysed not only as the sum of its parts but as a whole in which interactions between individual components are crucial to understanding its functioning and dynamics [65]. David Godschalk [42] conducts research on resilience, drawing a similar understanding of the city to Li and Zhao's, and points out that it is a multidimensional process. Resilience should consider the integration of all urban systems: infrastructure, economy, environment, and society, i.e., a holistic approach to urban systems, without rejecting any of them [42]. Another important approach to building urban resilience is based on innovation, which often catalyses change in the city [64]. Davoudi and his team [23] base their understanding of urban resilience on this innovative approach to the city. They point out that resilience is the ability to adapt to future challenges. This ability can be achieved through innovations in the management of urban spaces and through the development of adaptation policies, including those stemming from Nature-Based Solutions. Meerow [75] approaches the issue of urban resilience similarly to Davoudi, also focusing on innovations in creating resilience, such as green roofs, Miyawaki's forest pockets, or smart city technologies, but in her considerations, she indicates that the time it takes for the disturbed urban organism to return to a state of equilibrium is important. Meerow and Newell [74] proposed new concepts: an approach to defining urban resilience. Their definition emphasises that resilience is not only the ability to return to a state of equilibrium but also to evolve in response to change and uncertainty.

An important aspect of urban resilience is urban greenery, which strengthens the functioning of the city as a complex socio-ecological system. The environmental approach to urban resilience is based on increasing cities' ability to maintain equilibrium and adapt by protecting and restoring ecosystems [114], [44], leading to the implementation of solutions such as green infrastructure and preparations for future environmental challenges [76]. Consequently, green areas become one of the key elements supporting this resilience. Their importance is growing, especially amid climate change, which is increasing the frequency of extreme weather events such as heat waves, floods, and droughts. In response to these threats, urban greenery serves as a nature-based solution that mitigates their effects [79]. Increasing biologically active surfaces promotes stormwater retention, reducing the risk of flooding and slowing stormwater runoff [36], thus strengthening the resilience of urban infrastructure

[60]. At the same time, the impact of green spaces extends beyond the environmental dimension and affects the social sphere, as their availability improves residents' mental well-being, supports regeneration, and reduces stress [116]. This, in turn, promotes greater use of public spaces, such as parks and community gardens that integrate residents and thus strengthen social capital [54], an element of urban resilience. In addition, green spaces are a crucial element of urban policies and strategic documents, as urban greenery also brings economic benefits. It increases property values, enhances the city's investment attractiveness, and reduces costs related to public health and extreme weather events. For this reason, contemporary urban development strategies consider green infrastructure a tool for strengthening cities' potential [49].

The concept of urban resilience, based on research conducted in numerous centres, emphasises the integration of management, technology, innovation, and environmental protection to increase cities' ability to adapt, survive, and thrive in the face of crises [17].

3. AIM, METHODS AND TIMEFRAME OF THE STUDY

The aim of this study is to conduct a review and bibliometric analysis of the scientific literature on urban resilience to identify current and dominant dimensions of the concept.

The study was divided into three stages:

- The first, conceptual stage included establishing the study objective, defining the time frame, and conducting a literature review.
- The second, analytical stage involved quantitative, keyword-based bibliographic and network analyses using VOSviewer.
- The third, synthetic stage included a synthesis of the results and conclusions, along with a summary of the study.

The analyses included:

1. Selection of the primary database based on the occurrence of the main search phrase "urban resilience" in the title, abstract, and keywords in Scopus and Web of Science according to the query (TITLE ("urban resilience") OR ABS ("urban resilience") OR KEY ("urban resilience")) AND PUBYEAR > 2009 AND PUBYEAR < 2026.
2. Extraction of articles from the primary database containing the term in their keywords according to the query KEY ("urban resilience") AND PUBYEAR > 2009 AND PUBYEAR < 2026.
3. Creation of a keyword co-occurrence network map.
4. Definition of clusters representing dimensions of urban resilience, constituting complementary search phrases.
5. Quantitative analysis of the total number of occurrences of the main and complementary search phrases in the title, abstract, and keywords in Scopus.
6. Creation of a keyword co-occurrence network map for the environmental dimension of urban resilience based on a database of articles prepared based on the query (TITLE-ABS-KEY ("urban resilience") AND TITLE-ABS-KEY ("environment") AND TITLE-ABS-KEY ("green")) AND PUBYEAR > 2009 AND PUBYEAR < 2026

Bibliometric analysis quantitatively examines scientific publications and their relationships to identify research trends, dominant topics, knowledge structures, and development dynamics within a discipline.

It uses bibliographic data, including citations, authorship, keywords, and scientific collaborations [24]. It also relies on network analysis and keyword co-occurrence to examine keyword frequencies [19]. The study used VOSviewer to identify keyword relationships, group them into thematic clusters, structure the research area, and determine dominant dimensions [112].

The timeframe of the study covers the years 2010–2025. In 2010, the term "urban resilience" began to function as a clearly defined and intensively developed area of research [75]. Over the past decade or so, the number of scientific papers has increased significantly, reflecting the growing importance of urban resilience issues. This timeframe captures the most current research directions. The analysis utilized keywords exported directly from Scopus, without additional normalization or unification before import into VOSviewer. This methodological choice was made to accurately represent the structure of contemporary scientific discourse on urban resilience. Preserving the original keywords ensures consistency with Scopus metadata and minimizes the risk of subjective decisions regarding the merging of terms with potentially distinct meanings.

3.1. Novelty of the research

Despite the dynamic development of research on urban resilience, previous studies have focused primarily on defining the concept of urban resilience or analysing its selected dimensions. Proposed classifications in the literature vary in both the number and scope of the identified dimensions. However, there is a lack of an analytical framework based on quantitative analysis of current scientific literature that would organise urban resilience research.

The presented research addresses this gap by developing an analytical framework for urban resilience based on bibliometric analysis and keyword co-occurrence analysis. This allowed for the identification of five dimensions of urban resilience and an overarching meta-dimension, which is not just another dimension of resilience but rather serves as an integrating factor for all the other dimensions. Thus, the proposed framework expands on existing models of urban resilience, organising their structure and establishing a hierarchy of relationships between specific areas of research.

The analyses also enabled further development of the environmental dimension of urban resilience through the conceptualisation of green urban resilience. The contribution of this article is not to formulate a new theory of urban resilience but to integrate dispersed research streams. In the proposed approach, green urban resilience expands upon the environmental dimension of urban resilience, highlighting the crucial role of natural resources and green infrastructure in shaping a city's ability to adapt, absorb, and transform in response to contemporary threats.

4. RESEARCH RESULTS

Initially, records from the Web of Science (4,662) and Scopus (6,812) databases containing the keyword phrase "urban resilience" in the title, abstract, or keywords were identified. The results were then compared to detect and remove potential duplicate records across the databases. Scopus was chosen as the reference database for subsequent analysis due to its greater number of indexed publications and broader metadata coverage. Accordingly, all bibliometric analyses were performed exclusively on records from Scopus. In the final stage of data preparation, 2,268 Scopus publications that included the phrase "urban resilience" specifically in their keywords were selected. This refined dataset served as the foundation for further bibliometric analyses based on keyword co-occurrence.

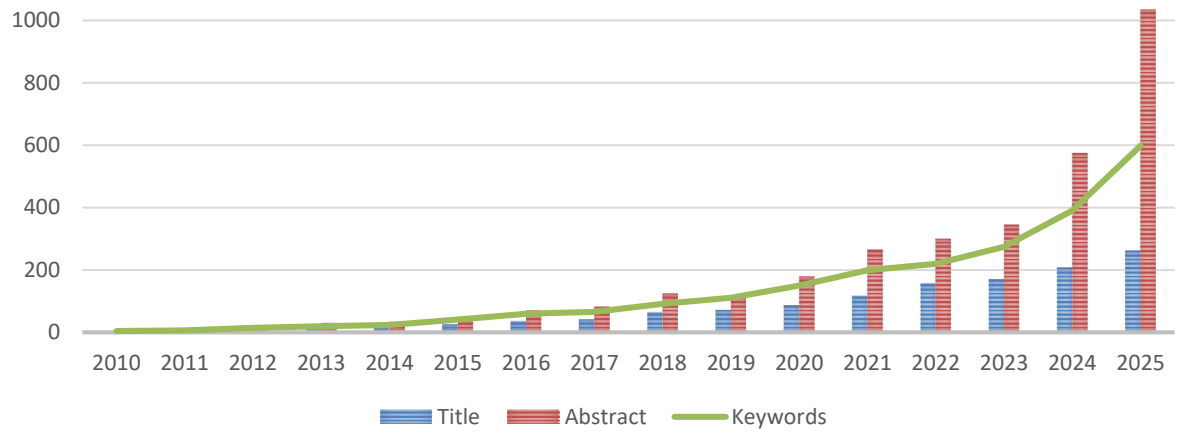

Fig. 1. Time distribution of the main search phrase in the title, keywords and abstract in 2010–2025
Source: own study based on the Scopus database

Analysing the annual frequency of occurrence of the main search phrase shows that interest in urban resilience has increased since 2018, with a particularly marked rise in occurrences in the abstract and keywords. Since 2018, there has been a steady increase in the number of publications addressing this topic in their research. The observed increase in publications during the analysed period may be associated with significant global events, such as the COVID-19 pandemic, which has intensified scholarly interest in urban resilience. Nevertheless, given the quantitative nature of the analysis, it is not possible to attribute these changes exclusively to this factor. Figure 1 illustrates the annual distribution of the main search phrase in publications indexed by the Scopus database.

After selecting the database, a network analysis was conducted using keyword co-occurrence analysis. At this stage of the research, a curated dataset comprising 2,268 scientific publications sourced from the Scopus database was utilised. This procedure enabled the development of a map of relationships between keywords and the identification of clusters reflecting the main research dimensions. As Gołaszewska-Kaczan [43] points out, map readability is important when creating keyword co-occurrence maps. Therefore, this study included keywords that occurred at least five times in the extracted dataset. Figure 2 presents the resulting keyword co-occurrence map.

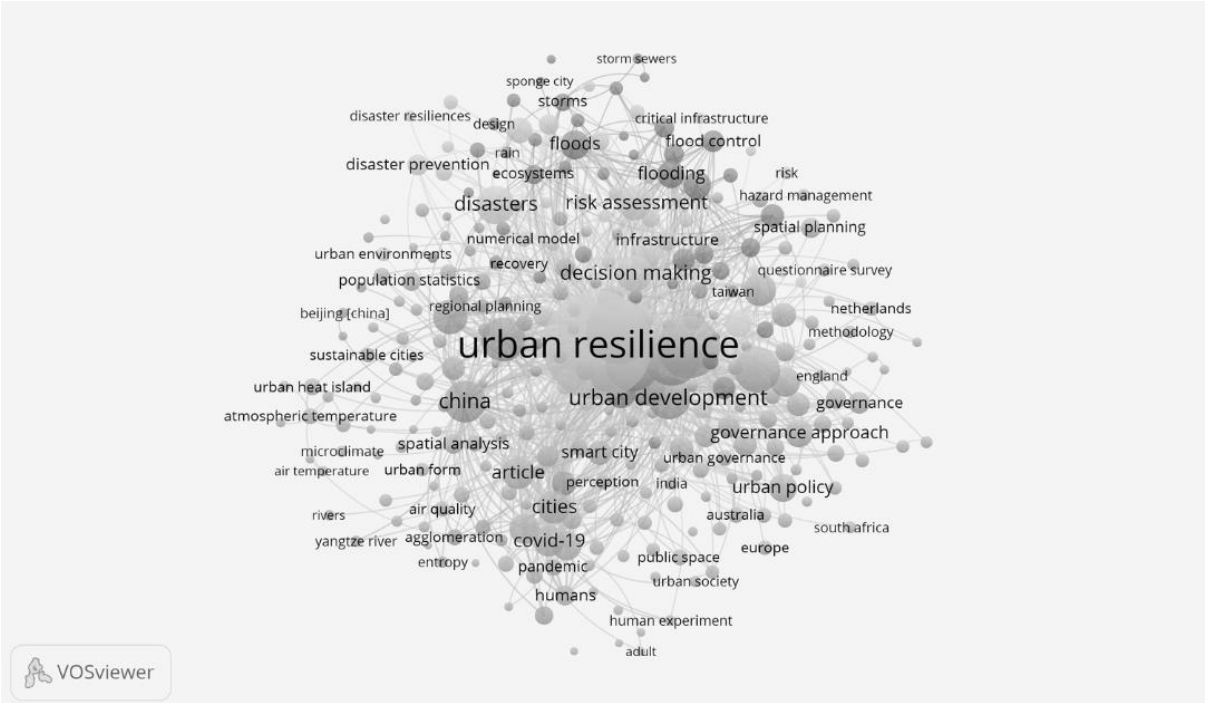

Fig. 2. Network co-occurrence of keywords
Source: prepared based on Scopus and VOSviewer.

Using the keyword co-occurrence procedure allowed us to identify the dimensions in which the topic of urban resilience is addressed, enabling further analysis of the concept's individual dimensions. Network analysis identified five main clusters (environment, society, infrastructure, economy, and governance) and one overarching cluster that serves as an integrating node connecting the remaining research areas. These thematic categories formed the basis for defining the current dimensions of urban resilience. Five current dimensions were identified: administrative-managerial, infrastructural-spatial, environmental, economic, and social.

After identifying the dimensions currently represented in scientific discourse on urban resilience, we examined their quantitative representation in the scientific literature. The identified main clusters were adopted as supplementary search phrases for further bibliometric analyses.

In this part of the study, the main search phrase was combined with a supplementary search phrase. The resulting pairs of search phrases were analysed for co-occurrence in the title, abstract, and keywords in the Scopus database. Based on the two-component analysis, the social and economic dimensions remain relatively underdeveloped in urban resilience research. Environmental issues, despite their growing importance amid the ongoing climate crisis, do not occupy a leading position within the structure of connections to the concept of urban resilience. Thematic areas focused on governance and infrastructure dominate (see Table 1).

Table 1. Analysis of the occurrence of the main search phrase and the supplementary search phrase in the Scopus database

Main and supplementary search phrases	Title	Abstract	Keywords	Total
urban resilience + society	8	186	30	224
urban resilience + environment	19	699	137	855
urban resilience + infrastructure	50	929	317	1,296
urban resilience + economy	19	213	93	325
urban resilience + management	57	878	537	1,472

Source: own study, prepared based on the Scopus database (as of February 7, 2026)

The final part of the bibliometric analysis included in-depth studies of the environmental dimension of urban resilience. A search of scientific articles containing the search phrases urban resilience, environment, and green in their titles, abstracts, and keywords was conducted in the Scopus database. Based on the database search, 142 scientific articles published between 2010 and 2025 were selected. To identify the dominant research directions related to the environmental dimension of urban resilience, a keyword co-occurrence analysis was conducted. The network structure revealed four distinct but interrelated clusters, reflecting separate subdimensions of research on environmental aspects of urban resilience.

5. DIMENSIONS OF URBAN RESILIENCE: PROPOSED ANALYTICAL FRAMEWORK

The analyses revealed an integrating node: the disruption dimension. Its identification indicates that various disruptions are integral to urban resilience. It is characterised by the highest level of interconnection and strong correlation with other dimensions, indicating its overarching nature.

This high centrality means the disruption dimension serves as an integrating axis around which the remaining elements of the urban resilience system are organised. It does not describe a single, discrete area of a city's functioning, but rather refers to a universal set of stimuli and pressures affecting all its spheres. Consequently, it cannot be treated on an equal footing with other sectoral dimensions that relate to specific areas.

The disruption dimension should therefore be interpreted as a set of primary determinants influencing the individual dimensions of resilience: administrative and managerial, infrastructural and spatial, environmental, economic, and social. Disruptions serve as initiating factors and determine the development and specificity of each dimension. Their nature, scale, and frequency define management needs, shape infrastructure development and spatial planning, determine environmental pressures, influence the stability of economic systems, and impact social processes.

From this perspective, the disruption dimension is paramount, as it establishes an interpretative framework for the other dimensions and determines how they are identified and operationalised. However, it does not constitute a standalone category within urban resilience but rather a meta-dimension that permeates the others and gives them analytical meaning, thereby confirming its central

role in structuring the entire concept. This distinction should be kept clear when interpreting the framework.

5.1. Administrative-managerial dimension

Urban resilience in the context of urban governance refers to the ability of city authorities and management systems to anticipate, prepare for, respond to, and adapt to challenges such as natural disasters, climate change, and social and technological crises [41]. In the literature on urban resilience, it is often analysed within the framework of multi-level governance, encompassing the national, regional, and local levels [28]. A key element in managing urban resilience at the national level is the creation of a supportive framework of policies and principles that should positively impact resilience [20]. Systems thinking is crucial in developing national policies. A systems approach to framing urban policies is crucial for understanding and managing the complex interdependencies between various elements of urban resilience. Without an appropriate legal framework, legislative tools, and programmes, building urban resilience would be significantly hindered [104]. Elkhidir et al. [32] point to the need to establish national resilience knowledge networks that would institutionalise knowledge sharing, collaboration, and the standardisation of resilience approaches, thereby creating consistent national standards for urban resilience.

According to Dieperink [28], the regional level in urban resilience management serves as a coordination point between national policy and local activities, particularly in spatial planning, social policy, water management, and flood risk management. It enables the integration of multiple municipalities and institutions within a single functional area, thereby increasing the effectiveness of resilience-building.

From a local perspective, as Struggles [107] points out, local government is closest to the problems that may arise in cities. Struggles also points out that a crucial element in resilience management at the local level is cooperation with other levels of government, as well as public and private entities. Furthermore, the local dimension of resilience activities must be consistent with national policy principles, but above all, take into account the principles of sustainable development [16].

As Knodt et al. [57] point out, the systemic management model becomes particularly important in crisis situations, when rapid and efficient information exchange becomes crucial. The authors distinguish three basic types of critical infrastructure management at the local level: a hierarchical model, based on formal structures and centralised decision-making; a network model, based on cooperation and partnerships; and a market model, utilising competitive mechanisms. In this context, network management is particularly important, as it constitutes a crucial tool for shaping the administrative and managerial dimension of urban resilience. It enables effective coordination of activities among the various entities involved in the city's functioning, which is especially important in crisis situations [88].

The dimension of resilience management at the local level is characterised primarily by the flexibility of local government bodies and their proximity to emerging crises [31]. Local authorities and organisations are closer to the real challenges and needs of residents, which enables a faster response to crises [99]. Local governance also encompasses collaboration with residents, non-governmental organisations, and local businesses in decision-making processes, including the development of district-level adaptation plans, e.g., integrating green urban spaces into blue-green infrastructure [35]. Effective urban governance in the context of urban resilience requires synergy between central and local activities. Local entities ensure flexibility and adaptation to local conditions, while central institutions provide the framework, financing, and broad-based coordination. Only such a multi-level approach will enable the building of cities resilient to future challenges.

5.2. Infrastructural-spatial dimension

Infrastructure plays a key role in building urban resilience [92]. High-quality technical infrastructure increases cities' ability to cope with threats by minimising losses and enabling the rapid restoration of normal urban functions [62]. It encompasses transportation, energy, water and sewage networks, flood protection systems, and crucial blue-green infrastructure (e.g., parks and retention reservoirs) in the context of a climate crisis. Infrastructure and urban space play a key role in building urban resilience, encompassing not only technical aspects but also the design and organisation of green areas and public spaces, as well as the city's functional and spatial structure. As emphasised by researchers [122], [93], [5], [61], appropriate spatial management, the integration of blue-green infrastructure, and resident participation in planning can mitigate the impact of threats and strengthen cities' adaptive capacity.

Urban infrastructure must be properly planned to minimise the negative impact of potential disruptions. It can be designed based on the principles of diversification and decentralisation of systems, so that the failure of one element does not paralyse the entire system, as discussed extensively by Rinaldi, Peerenboom, and Kelly [98] in their analysis of critical infrastructure interdependencies and by Ouyang [84] in their review of the literature on infrastructure system resilience. Planning based on risk analysis and the identification of intersectoral dependencies is also crucial, allowing for the mitigation of cascading failures and ensuring business continuity in crisis situations [86], [39]. Furthermore, intelligent management of urban infrastructure is crucial [13]. In the context of urban resilience, this means using advanced technologies, data, and innovative strategies for design, monitoring, and management that increase resilience to disasters, climate change, and other challenges [103]. Intelligent infrastructure management, such as early warning systems, increases the ability to respond quickly to crises [22].

Damage to key infrastructure elements can lead to cascading failures in urban systems, such as blackouts, transport disruptions, or water shortages, thereby weakening a city's resilience [108]. Sustainable and resilient infrastructure (e.g., earthquake-resistant buildings, stormwater management systems) reduces the risks associated with extreme events such as floods and droughts [119].

5.3. Environmental dimension

The environmental dimension of the urban resilience concept focuses on cities' ability to adapt through their environmental components. The natural environment plays a key role as an adaptive factor. Actions within this dimension support cities' ability to absorb CO_2, regulate temperature, and reduce the risk of extreme weather events (e.g., floods) through natural defence mechanisms such as blue-green infrastructure and nature-based solutions [120], [33]. It emphasises protecting biodiversity in cities, which is important not only for ecosystem health but also for residents' quality of life [101]. Green areas also play an important psychological role, promoting stress reduction, improved well-being, and mental regeneration for city residents. Increasing the number and improving the quality of urban green areas support local ecosystems and contribute to air and water purification [10].

The environmental dimension is closely associated with green infrastructure in cities, or more broadly, with blue-green infrastructure [62]. Blue-green infrastructure, understood as a network of natural and semi-natural spaces, positively influences urban resilience [87]. Green areas in cities primarily influence the hydrological cycle, reducing the risk of floods and droughts [40]. This dimension also plays a significant role in cooling cities. Green areas reduce the urban heat island effect by providing shading, increasing evaporation, and improving air circulation, thereby lowering temperatures in urban areas [81]. Urban resilience and adaptation to climate change are complementary strategies that help cities cope with climate uncertainty. In this dimension, protecting biodiversity and improving air and

water quality are also important [80]. Vegetation in cities filters air pollutants and supports stormwater purification, stimulating the development of urban resilience [48].

This dimension is a key element that enables cities to achieve sustainable development amid rapid societal and environmental transformations. These efforts require an interdisciplinary approach combining urban planning, environmental engineering, and social engagement. The environmental dimension of urban resilience and the natural environment enable the construction of cities that are more resilient to crises, particularly environmental ones. However, an integrated approach to planning, financing, and management is required to achieve long-term positive effects in the context of urban resilience [106].

5.4. Economic dimension

The economic dimension of the urban resilience concept refers to cities' ability to build resilience to threats and changes through actions that support economic stability and development [2]. It focuses on economic strategies that help cities withstand crises, mitigate financial losses, and stimulate long-term growth.

Urban resilience in its economic dimension encompasses actions that support the local economy, such as economic diversification [12]. Reducing dependence on a single industry helps cities cope better with economic crises, while economic monoculture lowers resilience [27]. Antifragility is also important: economically antifragile cities can not only withstand crises but also strengthen their development potential amid disruption and uncertainty. They can use crises to diversify their economies, develop innovation, strengthen local entrepreneurship networks, and increase the flexibility of the labour market and financial systems [110], [15]. A flood, for example, can severely affect a specific economic sector, reduce city budget revenues, and generate high rebuilding costs, delaying a return to the pre-disruption state [111]. Detroit illustrates this point: deindustrialisation and the collapse of the automotive industry led to population decline, a crisis in public finances, and bankruptcy [66].

The economic dimension also includes asset protection, which helps sustain economic activity and stable development. It involves securing public assets, such as infrastructure, public utilities, and transport networks, as well as private assets, including real estate, businesses, and productive capital, from climatic, technological, and economic shocks. Asset losses are among the main drivers of long-term local economic destabilisation [47].

Economic resilience also depends on investing in sectors and solutions that improve financial stability and reduce vulnerability to external shocks. Low-carbon infrastructure, including green buildings and public transport, can reduce energy costs and dependence on volatile commodity markets [16], [82]. These investments also bring indirect benefits, such as improved air quality and residents' health, which can reduce long-term public healthcare spending [81]. Cities that invest in sustainable infrastructure also become more competitive and attractive to investors. Creative industries also play a significant role: according to Richard Florida's creative class concept, they foster innovation, attract highly skilled specialists, and strengthen the local knowledge-based economy [37]. Greater investment attractiveness can attract private capital and external funds, which can be reinvested in further adaptation measures. In this way, investments in resilience strengthen local economic capital and improve environmental outcomes. The economic dimension of urban resilience is therefore becoming part of strategic development management, not only a response to crises. Sustainable investments, economic diversification, and reduced inequalities make cities more resilient to economic crises and support their long-term stability and competitiveness [1], [47].

5.5. Social dimension

The social dimension of urban resilience refers to the mechanisms and social resources that enable residents to function effectively during crises and recover quickly. The literature primarily emphasises the need to strengthen social well-being, build strong bonds and social capital, and ensure equal access to resources, services, and support mechanisms, all of which constitute the foundation of social justice [21], [4]. Therefore, a socially resilient city strives to create an inclusive environment that takes into account the needs of seniors, people with disabilities, and groups at risk of exclusion, minimising inequalities and enhancing the entire community's ability to respond collectively to crises [117], [102]. This means, among other things, providing accessible public infrastructure, developing care and healthcare services, and adapting crisis communication systems to the needs of various social groups, all of which are crucial for increasing the safety and well-being of residents. In addition, the involvement of residents in decision-making processes is crucial, strengthening a sense of agency and trust in public institutions and improving the community's adaptability to shocks. In this way, social capital is built, which in crisis situations constitutes a key resource enabling rapid mobilisation and solidarity-based action. A network of relationships, trust, and cooperation among residents therefore plays a key role in increasing social resilience [30].

Providing access to resources such as housing, education, and healthcare for residents, particularly those at risk of social exclusion reduces their vulnerability to threats and, in turn, positively influences social resilience [120]. In the context of creating socially resilient cities, raising awareness and educating residents about threats and mitigation strategies are also crucial [6], [72]. Examples include educational programmes in schools and local communities on climate change and coping with its effects, as well as information campaigns that support residents' preparedness for natural disasters, such as earthquakes [56].

Well-designed public spaces that incorporate green areas into the urban fabric not only promote improved mental health and reduce stress but also strengthen social bonds and social capital [54]. Research shows that the shared use of green spaces increases residents' trust and integration, which facilitates mobilisation and solidarity in crisis situations. Thus, biophilic urban design and the development of accessible green spaces are important elements in building social resilience, as they combine improved individual well-being with strengthened local community cohesion [59].

6. TOWARDS A GREEN URBAN RESILIENCE

The environmental dimension of the urban resilience concept was selected for further in-depth literature review, as it is fundamental to the functioning of urban systems and directly determines their capacity for adaptation, regeneration, and long-term development. The natural environment is a key element shaping urban resilience, and its role in the context of contemporary challenges continues to grow [105].

Green areas and natural resources not only mitigate the negative effects of climate change but also have impacts that extend across multiple dimensions of resilience [40]. Their influence extends beyond the environmental sphere to include improving social well-being, strengthening local ties, increasing the value of public spaces, and shaping investment attractiveness and urban aesthetics [89].

In the literature, there is growing interest in the environmental dimension of urban resilience. Both the number of publications and the broadening of thematic scope are evident, encompassing issues of ecological infrastructure, climate adaptation, ecosystem services, water management, and sustainable spatial planning [75]. At the same time, this area is characterised by a high degree of interdisciplinarity, integrating knowledge from environmental sciences, urban planning, geography, urban engineering, economics, and the social sciences [105]. This interdisciplinarity makes it a particularly valuable area

for bibliometric analyses, which allow for the identification of trends, dominant themes, and research gaps. The importance of the natural environment in cities is currently being reinterpreted. It is perceived not only as an aesthetic element but also as a key factor influencing quality of life and residents' health, as well as building resilience to climate change [3]. Greenery is increasingly integrated with urban infrastructure and treated as an essential component of sustainable development.

The choice of the environmental dimension for further bibliometric research is justified by its important role in building urban resilience, its broad impact on other resilience dimensions, and its growing prominence in scientific discourse on sustainable and resilient urban development. This focus will enable a better understanding of the relationship between the environment and the functioning and adaptability of urban systems, as well as the identification of key trends and future research directions.

6.1. Current Directions in Research on the Environmental Dimension of Urban Resilience

To identify thematic clusters, or subdimensions, of the environmental dimension of urban resilience, a network analysis was conducted using keyword co-occurrence analysis. This analysis identified four subdimensions discussed in the scientific literature on the environmental aspects of urban resilience: green infrastructure, climate change, spatial analysis, and urban planning.

The first subdimension, **"green infrastructure"**, focuses on concepts such as urban resilience, green infrastructure, urban sustainability, ecosystems, and biodiversity. It encompasses studies that consider resilience as an integrated effect of the functioning of environmental components in cities and emphasise the importance of green infrastructure in increasing adaptive capacity. The dominant themes here are ecosystem services, the role of urban greenery in disaster risk reduction, and the synergies between resilience and sustainable development.

The second subdimension, **"climate change"**, groups concepts related to climate change, urban heat island, air quality, sustainability, resilience, and urbanisation. Research in this area focuses on the impact of global climate change on urban environmental conditions and on ways to mitigate adverse phenomena such as heat islands and air quality degradation. The strong links between climate change and resilience are reflected in the growing number of publications highlighting the need to integrate climate adaptation into urban planning and policies grounded in urban resilience concepts. Greenery-based tools, such as green roofs and blue-green infrastructure, are also frequently analysed and assessed for their effectiveness under conditions of increasing climatic stress.

The third subdimension, **"spatial analyses"**, encompasses terms such as urban area, GIS, spatial analysis, cities, urban development, landscape, and population statistics. Its focus is clearly methodological – it examines the use of geoinformatics and spatial analyses to study urban resilience and the urbanisation processes that influence environmental functioning. This subdimension is dominated by empirical studies based on spatial data, often focusing on specific countries or regions (e.g., China, the USA). It also serves as a bridge between environmental analysis and urban policy research, enabling the identification of phenomena related to spatial resilience.

The fourth subdimension, **"urban planning"**, encompasses urban planning, green space, ecosystem services, urban design, and land use. It encompasses research on the role of spatial planning in creating conditions conducive to urban resilience. The focus is on the functional and spatial distribution of green spaces and their connection to various urban structures. Studies often utilise tools to assess ecosystem services and to model scenarios for changes in spatial development.

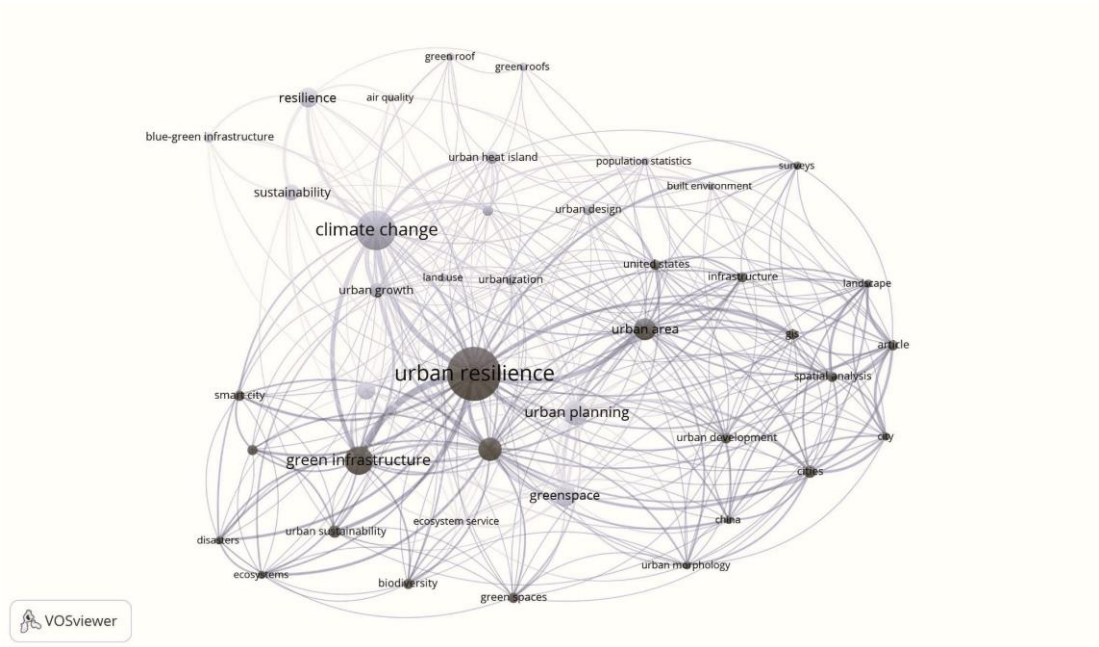

Fig. 3. Keyword co-occurrence network within the environmental dimension of urban resilience
Source: prepared based on Scopus and VOSviewer

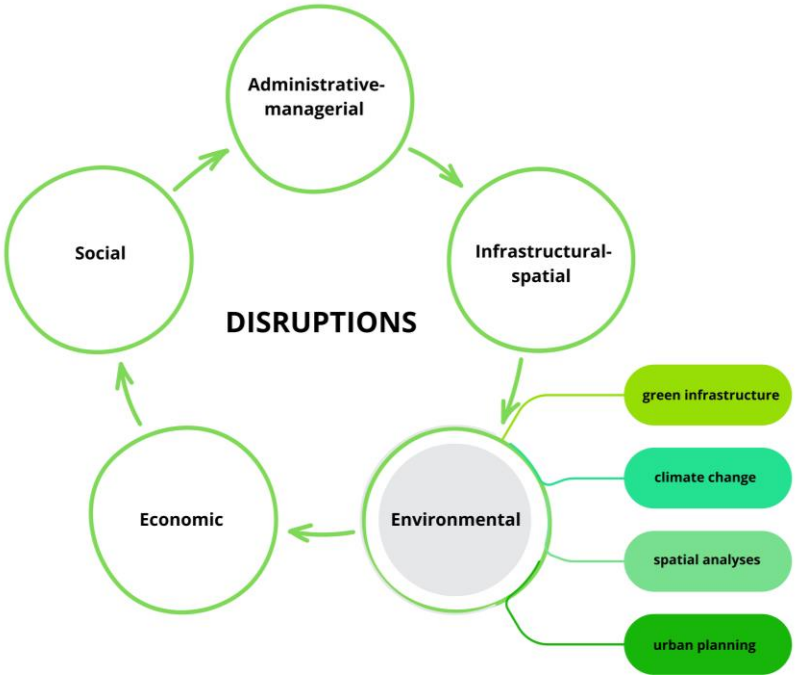

Fig. 4. Dimensions of urban resilience and subdimensions of the environmental dimension
Source: prepared by the author

Network analysis reveals strong interconnections between the four subdimensions, which together form a coherent knowledge system on the environmental dimension of urban resilience. Urban resilience is a key element that integrates the entire network, is situated at the centre of co-occurrence structures, and serves as a bridge between the other subdimensions. The green infrastructure subdimension remains strongly linked to the urban planning subdimension, reflecting the growing recognition that the design and management of urban spaces must increasingly rely on ecosystem mechanisms. At the same time, the climate change subdimension links resilience to environmental threats resulting from global trends. Spatial analyses enable the determination of the distribution of green infrastructure, the identification of areas vulnerable to climate risks, and the assessment of access to ecosystem services, making them a key approach for green resilience strategies. The relationships between the subdimensions clearly indicate that green urban resilience is emerging as a distinct research strand at the intersection of urban ecology, spatial planning, climate adaptation, and geoinformation. It is the coexistence of these domains that makes nature-based resilience a key direction for urban policies aimed at adaptation, risk reduction, and improvement in residents' quality of life.

6.2. Green urban resilience - an attempt at conceptualisation

The author's concept of green urban resilience is based on the four identified subdimensions of the environmental dimension. However, the remaining four dimensions are equally important and serve a complementary function, providing a broader context for this concept.

Green urban resilience expands the environmental dimension of urban resilience. It refers to a city's ability to absorb environmental pressures, adapt to them, and transform in response to them by drawing on natural resources and nature-based solutions. In light of the bibliometric analysis, it can be understood as an integrated system of activities, processes, and structures in which urban ecosystems and green infrastructure, along with their regulatory, supporting, and cultural functions, play a key role.

Green urban resilience emerges at the intersection of four main research areas: green infrastructure, climate change, spatial analysis, and urban planning. First, green infrastructure emphasises the importance of ecosystems and biodiversity as the foundation of a city's adaptive capacity, particularly by providing ecosystem services and mitigating the impacts of natural hazards. Second, green resilience is associated with mitigating and adapting to climate change, including reducing the urban heat island effect and improving air quality, often using solutions such as green roofs or blue-green infrastructure.

Another important component of green urban resilience is the infrastructural and spatial dimension, which enables the identification of areas exposed to environmental risks and the assessment of the availability and effectiveness of green infrastructure. Operationally, geoinformatics tools and spatial analyses provide the basis for making planning decisions. Finally, urban planning plays an operational role, integrating environmental elements with spatial development policies by appropriately shaping the structure of green areas and their functional connections.

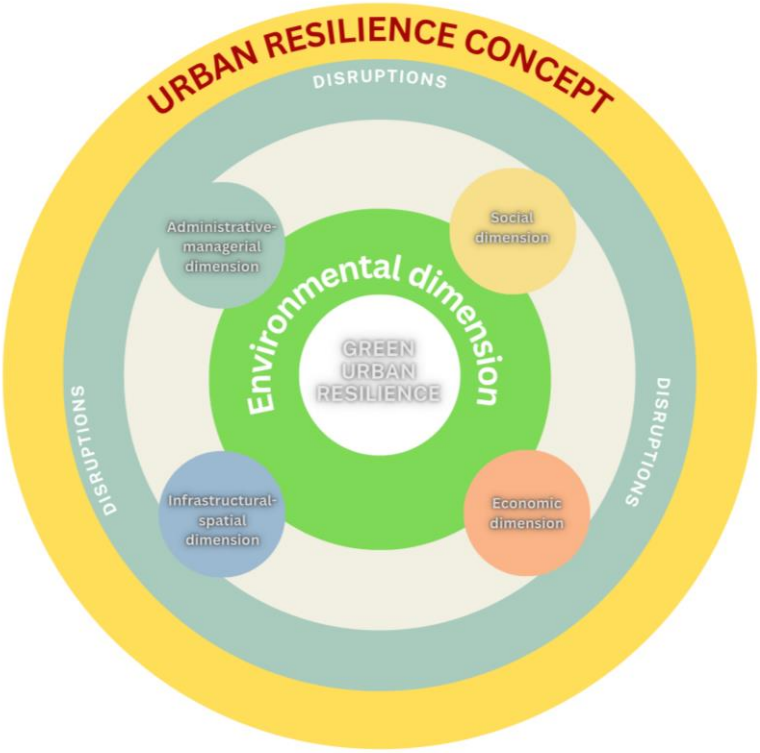

Fig. 5. Conceptual approach to green urban resilience
Source: prepared by the author

As a result, green urban resilience can be defined as the ability of an urban system to maintain and improve the quality of life of its inhabitants through the conscious use and enhancement of natural resources in planning, management, and adaptation processes. This holistic approach integrates ecological (green infrastructure), climatic (climate change), spatial (spatial analyses), and planning (urban planning) perspectives, positioning nature as a central factor in shaping the city's long-term stability and development.

The introduction of the original concept of "green urban resilience" represents a significant innovation in relation to the classical approach to urban resilience. While the traditional approach relies on a multidimensional assessment of the urban system's ability to absorb shocks, the proposed concept thoroughly operationalises and details the environmental dimension, redefining the role of natural structures. In green urban resilience, natural resources and blue-green infrastructure are no longer treated merely as supporting components or backdrops to urban development processes but rather as central and overarching elements. This stems from the fact that urban ecosystems and their functions (regulatory, supporting, and cultural) are defined here as the primary, autonomous foundation of a city's adaptive capacity. As a result, the transition from classical resilience to green resilience entails an evolution from the defensive protection of urban structures towards active, integrated urban management based on nature-based solutions.

7. DISCUSSION

Bibliometric analysis identifies research trends, conceptual structures, and thematic clusters across many phenomena. Its multidisciplinary nature and universality are used in numerous research fields. Applications include attempts to define key dimensions in education [124], current research in quantum physics [52], and the digital revolution in agriculture [11]. In each case, the analyses presented current research topics addressed in the phenomena under study.

The concept of urban resilience is increasingly analysed using bibliometric methods, which identify main research directions, collaboration networks, and the concept's evolution in the scientific literature. For example, Bautista-Puig et al. [9] conducted a bibliometric analysis of publications from the Web of Science database, focusing on links between urban resilience and sustainable development. Guo et al. [45] used bibliometric analysis to visualise the knowledge structure, map keywords, and identify the most important authors and research centres focusing on urban resilience. Kong et al. [58] presented a different approach, combining bibliometric analysis with visual analysis of research trends concerning the application of resilience theory in urban development. The authors analyse how urban resilience has developed, the main research directions, and the methods used to assess it. These studies use large databases and knowledge mapping tools but differ in scope. Some authors focus on the evolution of the concept and the structure of the discipline, while others focus on its relationship with sustainable development policy or its practical applications. A common feature is the pursuit of dominant themes, trends, and research gaps in the dynamically developing field of urban resilience [74], [78].

Polish researchers analyse urban resilience in the context of spatial planning, climate change adaptation, and urban development management, among other areas. Rogatka et al. [99], [100] focus on assessing the planning documents of the largest Polish cities and the extent to which urban resilience principles are implemented in spatial policy. Masik and Gajewski [70] examine the adaptive, absorptive, and transformative capacities of cities in the face of climate and socio-economic crises, emphasising strategic urban development management. Wereda et al. [115] analyse the role of ICT and the smart city concept in strengthening urban resilience, using survey research and quantitative methods. These studies share a systemic perception of the city as a complex social, environmental, and infrastructural structure. They differ mainly in research methods and scale of analysis. Some authors rely on strategic documents, while others use expert-based research or quantitative data on city functioning and digital tools [13], [22]. In the context of urban resilience, disruptions are sudden or long-term events that destabilise the functioning of the urban system. Meerow, Newell, and Stults [75] point out that urban resilience refers to a city's ability to maintain or quickly regain basic functions in the face of disruptions and to adapt to future threats. Holling [50], in developing the foundations of resilience theory, emphasised that disruptions play not only a destructive role but also stimulate processes of reorganisation and adaptation of socio-ecological systems. In urban resilience research, disruptions are therefore a key element in assessing cities' capacity to absorb crises, learn, and transform towards more sustainable development.

The identification of the disruption dimension in this study as a primary dimension in the context of urban resilience sharpens the approach proposed by Holling [50], in which disruptions were treated as a system element influencing the dynamics of its transformation. The previously mentioned taxonomies of urban resilience dimensions distinguished equivalent dimensions without a clear hierarchy of the role of disruptions. However, the network analysis indicates that disruptions serve as an axis that organises the relationships between dimensions. This makes the disruption dimension the central element, as it describes the nature of the pressure and the dynamics of the disruptions against which resilience is tested.

Based on their research on community resilience to disasters, Ostadtaghizadeh et al. [83] distinguished five dimensions of urban resilience: physical, natural, economic, institutional, and social. Ribeiro and Gonçalves [97] also conducted their own resilience analyses based on the aforementioned five dimensions. Delgado-Ramos and Guibrunet [26] identify four main dimensions of urban resilience: economic, ecological, socio-cultural, and governance. Kapucu et al. [55] present a different definition of these dimensions. They identify five main dimensions of urban resilience discussed in the scientific literature: environmental, infrastructural, economic, human, and institutional. These researchers define the dimensions of urban resilience in different ways and from different perspectives. Determining the dimensions of urban resilience depends on the adopted methodology and research approach. The dimensions identified in this study administrative-managerial, infrastructural-spatial, environmental, economic, and social confirm both the complexity of the issue under study and the multidimensionality of the concept. A different approach was presented by Yabe, Rao, and Ukkusuri [118], who analysed urban resilience through the interdependencies between a city's social and physical systems. The authors do not develop a classic multidimensional typology of urban resilience; instead, they focus on the relationships between local communities and critical infrastructure during recovery from natural disasters. This approach differs from previously presented taxonomies because it reduces the analysis to key functional relationships influencing the urban regeneration process, rather than distinguishing a broad catalogue of equivalent dimensions of the concept.

The networked connections within the environmental dimension between categories such as green infrastructure and climate change indicate a progressive ecological reinterpretation of urban resilience. This convergence is strongly supported by the literature. Zuniga-Teran et al. [123] emphasise that green infrastructure is a key component of resilience by reducing flood risk, mitigating the urban heat island effect, and improving air quality, among other benefits. Grimm [44], in turn, points out that cities function as complex systems whose stability depends on the quality of the relationship between the natural and social components. An ecological reinterpretation of urban resilience suggests that cities are socio-ecological systems, and resilience should be studied not only as the physical ability to return to a pre-disturbance state but also as the relationships among individual systems (or subsystems) within the city. As Ernston et al. [34] point out, however, urban ecosystems are crucial in this respect, serving as catalysts for urban resilience.

Green urban resilience is distinct from related concepts in the literature. Ecological resilience primarily addresses the resilience of ecosystems, while climate resilience concerns the capacity to adapt to climate change. Nature-based solutions and green infrastructure refer to interventions that employ natural processes and multifunctional green infrastructure elements [73], [38]. The present conceptualisation of green urban resilience does not supplant these approaches but rather integrates them within a broader urban resilience framework, positioning the natural environment as a co-creator of the urban system's capacity to respond to disturbances and adapt over the long term [73]. The proposed analytical framework aims to clarify the role of the natural environment within urban resilience and to delineate its connections with other dimensions of the concept.

7.1. Limitations of the study

This study presents methodological limitations that inform directions for future research. The selection of Scopus as the primary source of bibliographic data was based on the large number of publications on urban resilience, its broad journal coverage, unified metadata structure, and compatibility with VOSviewer software, which is widely used in bibliometric analyses [112], [29]. Scopus is among the most frequently utilised databases in bibliometric studies, facilitating comparability with previous research findings [7], [29]. However, reliance on a single bibliographic database may limit the scope of

the analysed research material, as databases vary in journal coverage and selection policies. The simultaneous use of multiple databases could potentially identify additional publications, though it is unlikely to fundamentally alter the main trends and thematic structures observed in this study.

Another limitation concerns the use of keyword co-occurrence analysis. While this method effectively identifies dominant research directions and relationships between topics, its results are influenced by the selection of keywords by publication authors and the indexing principles of the database [29]. Nevertheless, keyword co-occurrence remains a widely adopted and well-established approach in bibliometric research. The analysis was based on the primary search phrase "urban resilience," which is the predominant term in the scientific literature. Some relevant publications may employ alternative terms, such as climate resilience or urban adaptation. Expanding the search strategy to include additional phrases represents a promising direction for future research.

Despite these limitations, the research procedure enabled a comprehensive identification of contemporary research directions in urban resilience. It facilitated the development of a systematic conceptual framework that organises the main dimensions of this concept. Future studies could benefit from incorporating additional bibliographic databases and employing complementary bibliometric techniques, such as co-citation analysis, to provide a more comprehensive depiction of the evolution of urban resilience research.

8. SUMMARY AND CONCLUSIONS

The literature review and bibliometric analysis enabled the systematisation of research on urban resilience by identifying five dimensions: administrative-managerial, infrastructural-spatial, environmental, economic, and social. Furthermore, a significant contribution of this study to urban resilience research is the identification of the disruption dimension as the overarching dimension linking the other dimensions. This dimension does not function as a parallel analytical category but as a set of primary determinants, i.e., various disturbances that initiate the need for adaptation and organise the relationships between the other dimensions. This means that urban resilience should be interpreted not as a static equilibrium state but as a dynamic response of the urban system to disturbances, which determines the directions of further action.

However, keyword analysis indicates a clear asymmetry in how these areas are represented in the literature. The most frequently studied dimensions of urban resilience are administrative-managerial and infrastructural-spatial, reflecting researchers' growing interest in adaptive spatial planning, crisis management, and the technical aspects of urban resilience. The study also shows a relatively low representation of the social and economic dimensions in urban resilience research. The insufficient consideration of economic factors suggests the need for future research into the resilience of urban financial systems and the mechanisms that ensure their long-term stability amid crises. The social dimension of urban resilience should become a leading theme in research in the near future.

The environmental dimension is gaining particular importance in the discourse on urban resilience. In-depth bibliometric analysis reveals dynamic thematic developments, from which four dominant subdimensions emerge: green infrastructure, climate change, spatial analysis, and urban planning, confirming the growing greenisation of resilience discourse. At the same time, despite the increasing number of environmental publications, this dimension does not dominate the overall structure of the reviewed literature, giving way to administrative-managerial, and infrastructural-spatial issues. This indicates the need for further integration of the environmental component into mainstream urban resilience research. The study also operationalised the concept of green urban resilience as the ability of an urban system to absorb disruptions, adapt to them, and transform in response to them by leveraging natural resources, green infrastructure, and nature-based solutions. It encompasses the integration of

ecological, climatic, spatial, and planning aspects to mitigate environmental risks, strengthen the city's adaptive capacity, and maintain residents' quality of life.

The results of the analyses indicate that the concept of urban resilience is evolving toward a more multidimensional approach to city functioning, taking into account managerial, infrastructural, social, and environmental aspects. At the same time, the study indicates the need for further research on the relationships between the individual dimensions of resilience and on the role of disruption as a factor determining the adaptation processes of contemporary urban systems.

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