

A REVIEW OF RESILIENCE IN URBAN FORM FOR NATURAL DISASTER-PRONE AREAS

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Considering resilience within the components of urban form can aid in the planning of disaster-prone cities and enable them to become more resilient. Although prior research has explored resilience and urban form, the aspects of urban form that can enhance natural disaster resilience remain relatively underexplored. Thus, this study aims to identify these aspects and explore research opportunities in the development of resilience concepts in urban form that have been previously studied by researchers. This study employs the systematic review method, which includes bibliometric analysis and a full-text review of the identified literature. The results show that plots, open spaces, buildings, and streets are the main variables in developing a resilient urban form. Additionally, the street network within the urban form is emphasized in emergency disaster planning. Most current research describes resilience in terms of the ability to withstand and adapt by restoring and operating systems as they were before the disaster occurred. Recommendations for future research include focusing on long-term resilience in urban form by implementing new operational methods in cities to achieve transformative adaptation. Another opportunity is to conduct research in locations with unique characteristics in developing countries, especially areas that have previously experienced significant natural disasters. This study contributes to the understanding of how urban form can be enhanced for resilience through the planning of its components.

Key words: systematic review, disaster resilience, resilience, urban form.

INTRODUCTION

Cities that have previously experienced disasters, especially natural disasters, are not exempt from the possibility of their recurrence in the future. As urban centres continue to grow, urbanization in disaster prone-areas will inevitably increase. The global urbanization process continues to accelerate and is predicted to be most significant in urban areas (Feng *et al.*, 2020a). Urbanization influences the formation of a city both physically and non-physically. Therefore, disaster-prone cities have a vested interest in enhancing their resilience to disasters, which can potentially be achieved through urban forms that are capable of withstanding and adapting over time.

Cities exhibit changes in urban form over time. According to Cowan (2005), "urban form" refers to the physical manifestation of a city, which he also describes as synonymous with the urban

fabric. Additionally, he explains that the investigation and analysis of the physical structure and organization of urban areas is known as urban morphology. Živković (2019) clarifies that urban form is a term used to describe the physical characteristics of a city in terms of size, shape, and the configuration of the city or its parts, in order to understand its composition depending on the scale, also including non-physical aspects of urban form, such as density. The urban morphology approach is a method for analyzing the physical composition and layout of a city, focusing on buildings, streets, and plots that shape the overall appearance and structure (Oliveira, 2016). Yunus (2015) also suggests using the urban morphology approach to observe the physical development of a city and to understand urban morphology from two perspectives, namely:

- the urban form from spatial expression, which is formed by the expansion of the city; and
- the urban form from the pattern of the city's physical appearance; including the road system, buildings, and blocks.

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Northam (1975) and Pontoh and Kustiawan (2009) also propose that there are other ways to classify urban form besides spatial patterns, which are based on the arrangement of a city's components. In classifying urban form, the typo-morphological approach can be used, which involves grouping based on the structural characteristics of urban components (Kropf, 2017; Oliveira, 2016).

The urban form influences how resilient a city is in facing future disasters. Therefore, understanding an urban form that can withstand disasters is crucial for improving a city's resilience. The importance of incorporating resilience concepts into urban form planning cannot be overlooked, as it is essential to enhance resilience in preparation for future uncertainties (Jabareen, 2013). The concept of resilience is the capability of an urban system to evolve and implement effective short-term and long-term adaptation strategies aimed at reducing hazards, enduring and absorbing shocks, rapidly recovering basic functionality, and enhancing the system's ability to adapt more efficiently to disruptive events by evolving into a more advanced and robust system (Chelleri *et al.*, 2015; Desouza and Flanery, 2013; Sharifi and Yamagata, 2018a).

Resilience in urban form is demonstrated through the ability of its components to adapt, remain intact, and maintain functionality in the face of disasters across social, physical, institutional, environmental, and other systems (Felicetti and Romice, 2016; Sharifi and Yamagata, 2018b). Dhar and Khirfan (2017) propose the use of spatial, physical, functional, and ecological dimensions to assess resilience in urban form components. On the other hand, at a micro-scale, urban resilience can be observed in physical, environmental, social, and economic dimensions (Davis and Uffer, 2013). Previous studies indicate that there has been limited specific research on the concept of resilience to natural disasters and urban form. Natural disasters are often unexpected events that cause damage to cities and the people living in them, including meteorological, hydrological, geophysical, climatological, and biological disasters (Jha *et al.*, 2013).

This study addresses the need for resilient cities against natural disasters by clarifying the opportunities for future research through the aspects of resilience and urban form. Therefore, the aim of this research is to analyze the development of studies on urban form resilience and identify further research opportunities that need to be undertaken. The results of this review are beneficial for researchers studying urban morphology in order to delve deeper into the need for resilience against natural disasters, thereby assisting planners in developing strategies for resilient urban planning.

METHODS

This study employed systematic review and snowballing methods to select publications on the use of urban form for disaster resilience (Cooper, 2017; Thomé *et al.*, 2016). This method was considered most suitable for addressing the research objectives because it provides guidance for filtering the most relevant articles systematically. Articles were screened step by step using keywords, titles, and abstracts until a full-text review could be conducted. Figure 1 illustrates the

research stages. The first stage involved searching reputable international literature using various keyword combinations to maximize the relevance of search results to the topic, namely "urban form resilience", "urban form" AND "resilience", "urban form" AND "disaster resilience", and "urban form" AND "disaster". We attempted specific keyword combinations, however increasing the specificity of the keywords resulted in significantly fewer relevant results, often yielding minimal or no pertinent outcomes. Furthermore, the keywords included pertain to disasters in general, due to the broad nature of the resilience aspects in urban form being investigated. The primary search engines used were Scopus and Google Scholar, as both connect to a vast number of journal sources and align with the access available to the authors. To ensure the most recent developments were covered, the literature reviewed was limited to publications from the last ten years, specifically from 2013 to 2024. The literature was then selected based on its focus on urban studies and use of the English language. Additionally, related literature was identified through citation searches using Connected Paper to expand the literature search. This search engine was utilized due to its ability to filter articles that are most cited and relevant to the entered keywords, thereby beneficially enhancing the most relevant sources of search. Through online access, the most relevant articles appeared by entering the keywords "urban form resilience". Subsequently, the diagram and list displayed the analysis results of other articles based on keyword similarity, as well as presenting the most cited articles. Only literature that had undergone the peer review process was included to ensure that grey literature was excluded.

A total of 632 articles were found. First, articles were screened based on their title and abstract (n=184), followed by a full article review (n=45). The most relevant articles were then entered into VOSviewer to analyze any trends from bibliometric analysis: topic clusters and timeframe based on co-occurring terms, and the most contributing authors. Trend of journals with the most reputable contributions and reliability were visualized and used as the main publication sources for this topic, as well as the most frequently researched locations. Additionally, a full-text manual review was necessary to confirm the results from VOSviewer, highlighting the topic groups addressed and the limitations and future recommendations identified by the authors. These steps were undertaken to address the various aspects arising from the study of urban form resilience and to identify opportunities for urban researchers to further enhance knowledge in support of developing resilient cities.

RESULTS

The results of the bibliometric analysis are presented in the section Publication trends, while the findings from the full text review are displayed in the section Aspects of resilience and urban form. The final section is Limitations and recommendations from previous research.

Publication trends

The visualization from VOSviewer in Figure 2 shows the clustering of related keywords that are most frequently used together, revealing five topic clusters that emerge through these keywords. The first cluster is "resilience", which focuses on the robust characteristics of physical components. The most frequently appearing keyword

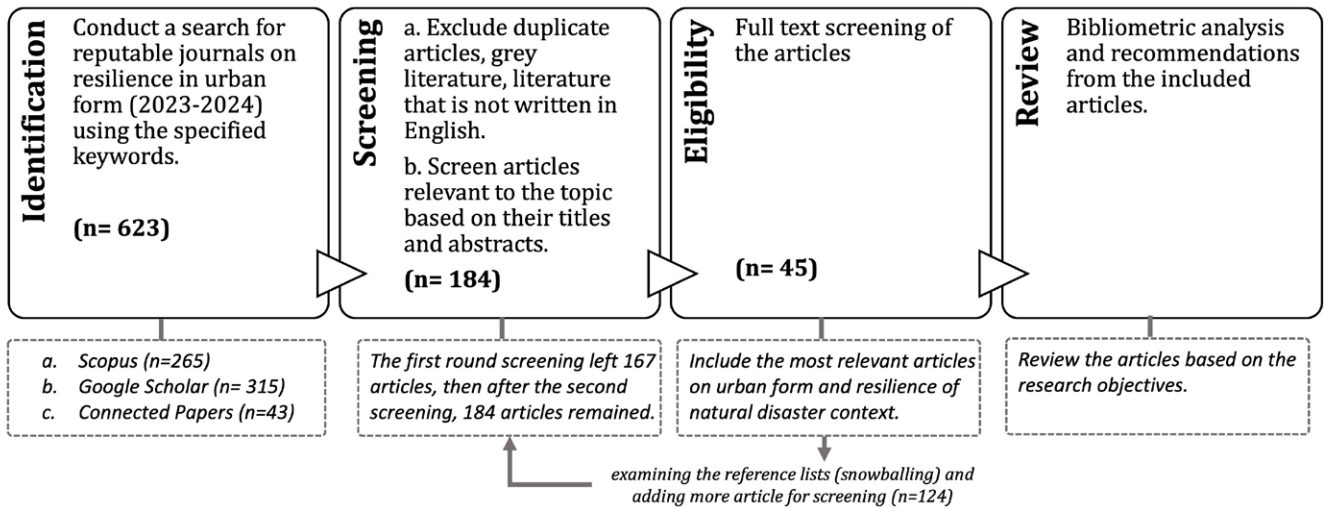


Figure 1. Research Stages (Source: Authors, 2024)

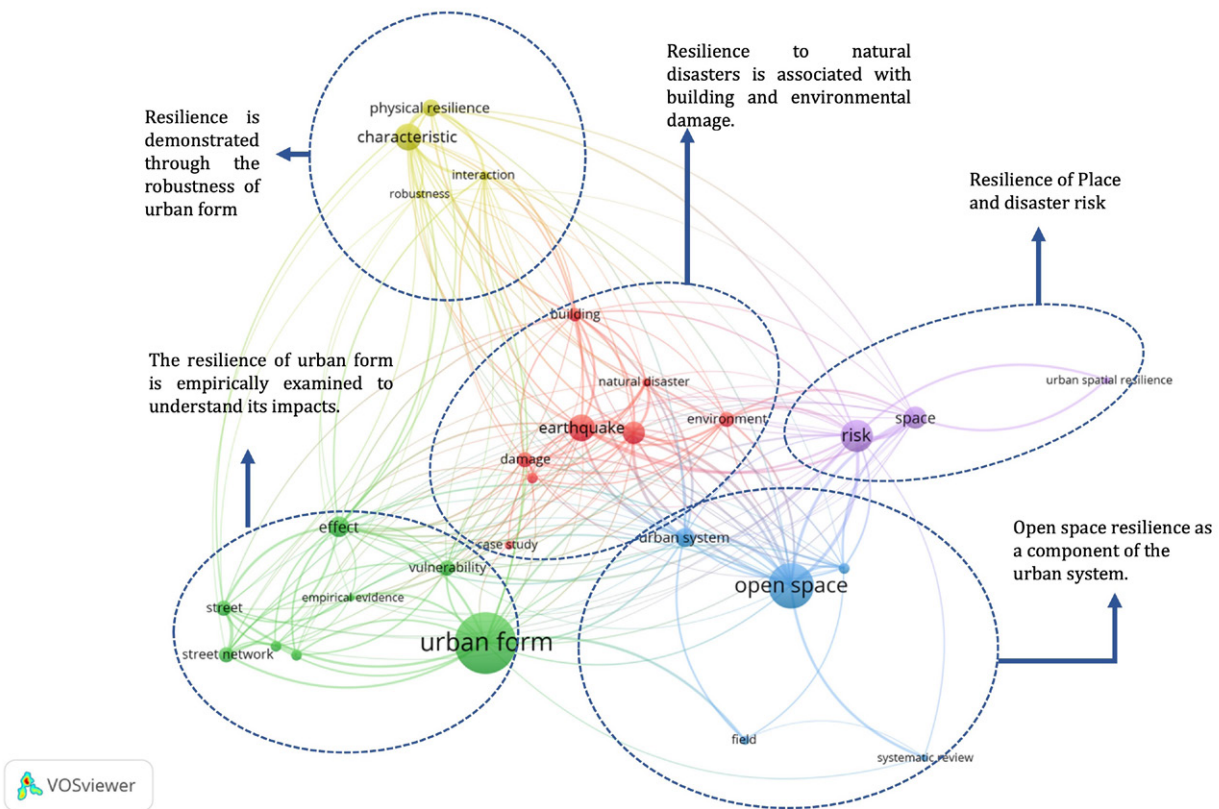


Figure 2. Most used terms in urban form resilience articles (Source: Authors, 2024)

is “character”, indicating the need for a full text review to determine what characteristics, besides robustness, are part of the resilience character. The second cluster is “resilience to natural disaster”, which relates to resilience against potential damage to buildings and the environment. The main keyword here is “earthquake”, highlighting that buildings and the environment are aspects of the urban form being studied. The third cluster addresses the resilience of urban form, with some studies already evaluating aspects of roads and their networks empirically. The main keyword in this cluster is “urban form”. The next cluster is “resilience of

place”, relating to disaster risk at specific locations, which has the fewest keywords in this group. The final cluster is the resilience of open spaces as part of the urban system. The most prominently used keyword is “open space”. This clustering provides guidance for further clarifying these clusters through the text review stages.

Figure 3 illustrates the timeframe of the most frequently occurring keywords from 2013-2024, revealing the latest trends in usage and discussion. All these keyword trends emerged after 2015, with the most prominent in the last five years being “physical resilience” and its characteristics,

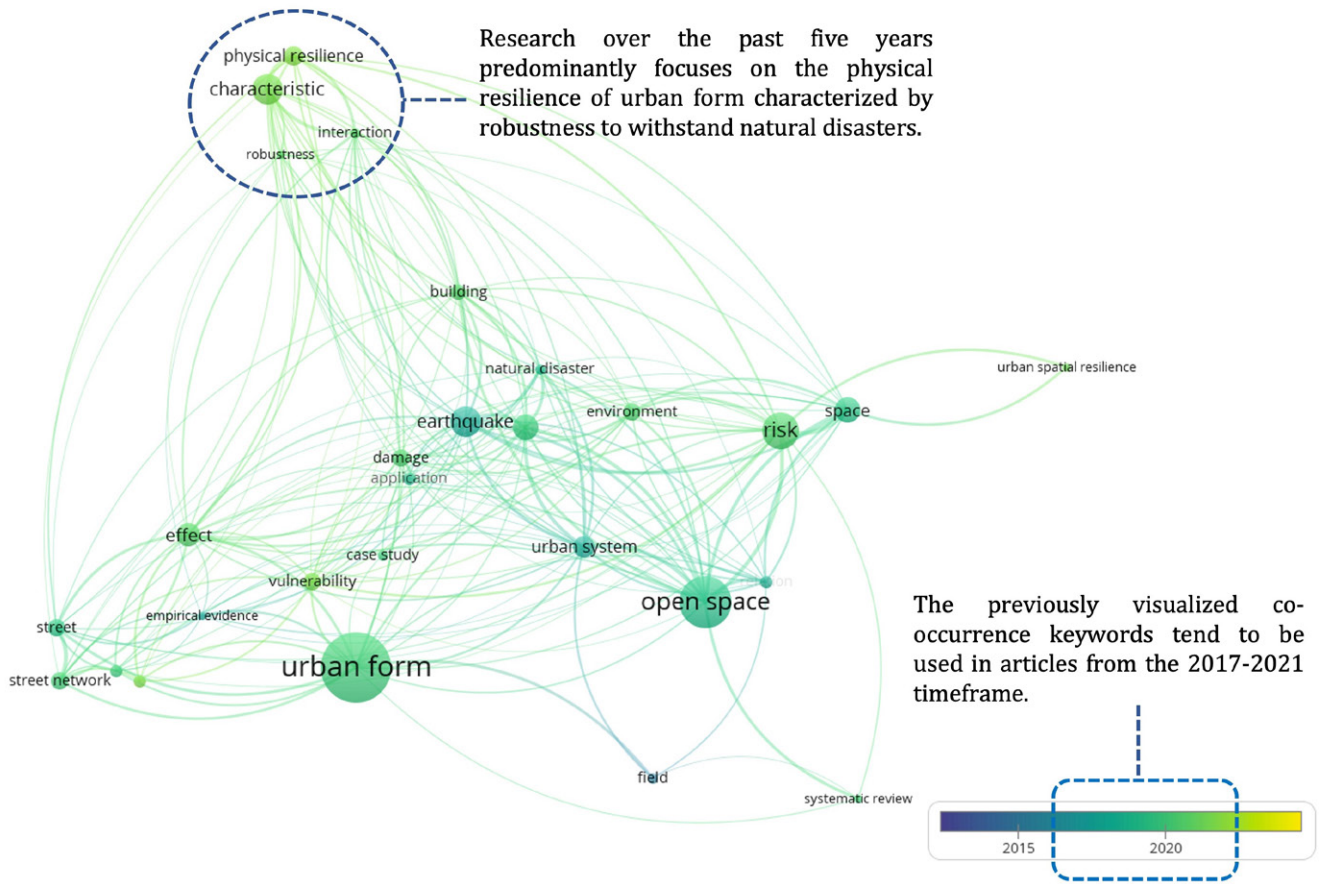


Figure 3. Timeframe of the co-occurrence keywords (Source: Authors, 2024)

as well as “interaction” and “robustness”. Figure 4 depicts the trend of the most researched locations, which tend to be in the Global South, indicating developing countries. The developmental status of each country may have different characteristics. However, the trend shows that the most researched locations are China and Iran. Not all studies reviewed provided location context, so the visualization presented represents trends from empirical studies. The analysis results also indicate, in Figures 5 and 6, the

authors and journals that have contributed the most to the publication of articles on resilience in urban form. For example, Ayyoob Sharifi is documented to have seven articles reviewed in this study and has collaborated with other researchers. Additionally, the journals that have contributed the most to research on urban form resilience are Urban Climate, Sustainability, and Cities.

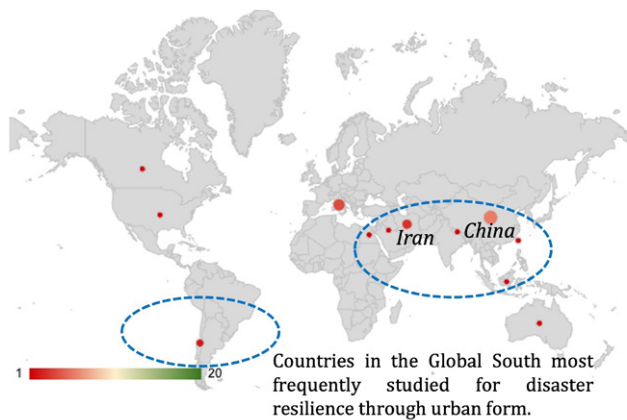


Figure 4. The most researched locations regarding urban form resilience to natural disasters (Source: Authors, 2024)

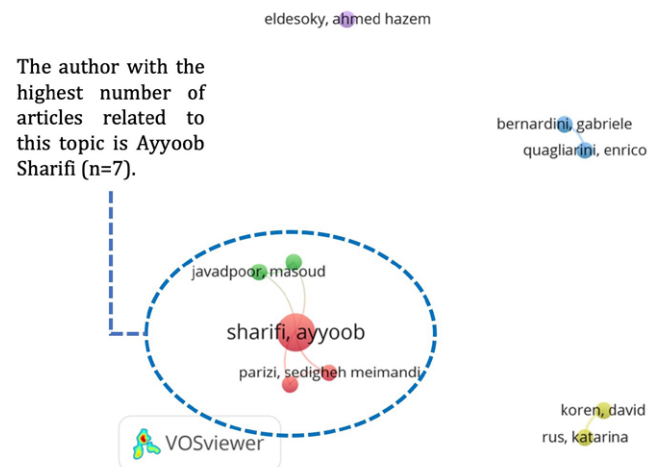


Figure 5. Authors who are most frequently recorded and belong to clusters that often collaborate in research (Source: Authors, 2024)

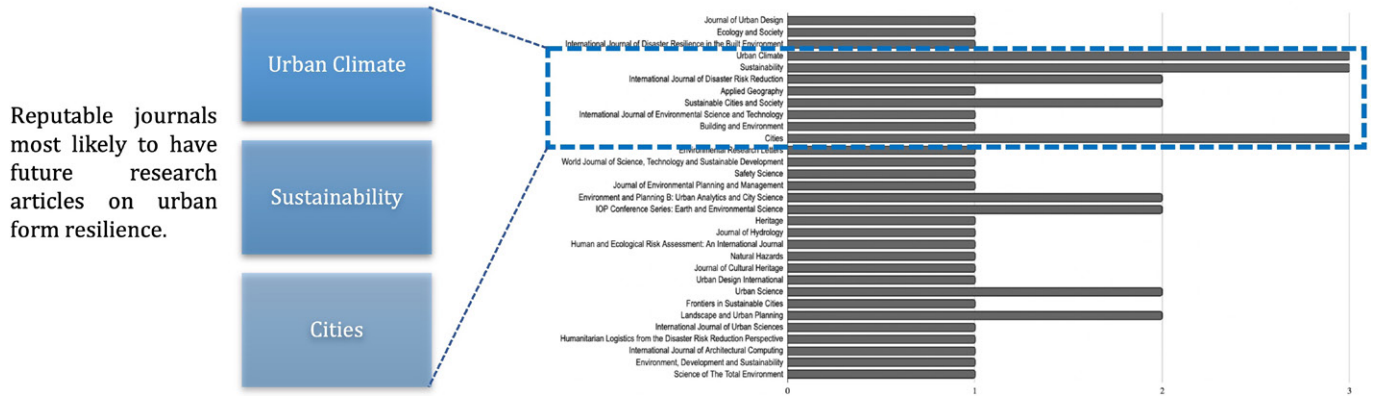


Figure 6. The journals with the highest number of publications on the reviewed topic (Source: Authors, 2024)

Table 1. Group of topics in urban form resilience to disaster

Group of Topics	References
Characteristics of Resilience in Urban Form	Marcus and Colding, 2014; Rus <i>et al.</i> , 2018; Sharifi and Yamagata, 2018b; French <i>et al.</i> , 2019; Masnavi <i>et al.</i> , 2019; Sharifi, 2019a, 2019b, 2019c; Lu <i>et al.</i> , 2021; Parizi <i>et al.</i> , 2021; Alawneh and Rashid, 2022; Parizi <i>et al.</i> , 2022; Eldesoky and Abdeldayem, 2023
Performance of Recovery and Adaptation of Urban Form in Disaster-Prone Areas	Irajifar <i>et al.</i> , 2016; Xu <i>et al.</i> , 2019; Feng <i>et al.</i> , 2020b; Sharifi <i>et al.</i> , 2021; Vicuña <i>et al.</i> , 2022; Ricafort & Makki, 2023; Xie <i>et al.</i> , 2023
Urban Form for Emergency and Evacuation Systems	Shrestha <i>et al.</i> , 2018; Koren and Rus, 2019; Giuliani <i>et al.</i> , 2020; Quagliarini <i>et al.</i> , 2021; Russo <i>et al.</i> , 2021; Roosta <i>et al.</i> , 2022; Li and Yan, 2024
Physical Strength of Urban Form	Fischer <i>et al.</i> , 2018; Wang, 2020; Li <i>et al.</i> , 2021; Liu <i>et al.</i> , 2024
Urban Design Strategy for Enhancing Urban Form Resilience	Allan <i>et al.</i> , 2013; Dhar and Khirfan, 2017; Hachem-Vermette, 2019; Abdulkareem <i>et al.</i> , 2020; Lak <i>et al.</i> , 2020; Gherri <i>et al.</i> , 2021a, 2021b; Sartorio <i>et al.</i> , 2021; Eldesoky <i>et al.</i> , 2022; Hao and Wang, 2022; Singh and Sharston, 2022; Ugalde <i>et al.</i> , 2022; Shukla and Makki, 2023; Xi <i>et al.</i> , 2023

Aspects of resilience and urban form

Based on a full text review of 45 articles, there are five topic groups that share similarities in research focus (Table 1). These topics are:

- Characteristics of Resilience in Urban Form;
- Performance of Recovery and Adaptation of Urban Form in Disaster-Prone Areas;
- Urban Form for Emergency and Evacuation System;
- Physical Strength of Urban Form; and
- Urban Design Strategy for Enhancing Urban Form Resilience.

In the timeframe of the development of group topics, all of them emerged as topics of research in the last five years (Figure 7), especially those addressing the use of urban design strategies.

Most of the research of urban form elements include streets, plots, and buildings. Apart from the research context, urban form is also associated with non-physical data, such as density, scale hierarchy, and diversity, while research in the context of landscapes uses forest, water, green open space, or green network variables. Specific research addresses specific infrastructure related to disasters, such as shelters and emergency routes. Most assessments of

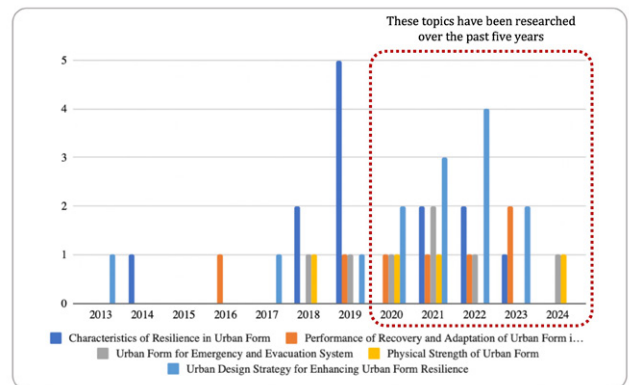


Figure 7. Timeframe of the research topic (Source: Authors, 2024)

the urban form led to connectivity, centrality, robustness, accessibility and efficiency. If viewed based on scale, the macro-scale component is land use/land cover, at the meso-scale it includes main roads, building blocks, open spaces, and nature areas, while at the smallest scale, it consists of buildings, plots, local roads, and local-scale open spaces. Figure 8 illustrates the resilience aspects that can emerge in urban form components, including: self-organization, coherence, interdependency, flexibility, responsiveness, creativity/innovation, diversity, redundancy, modularity,

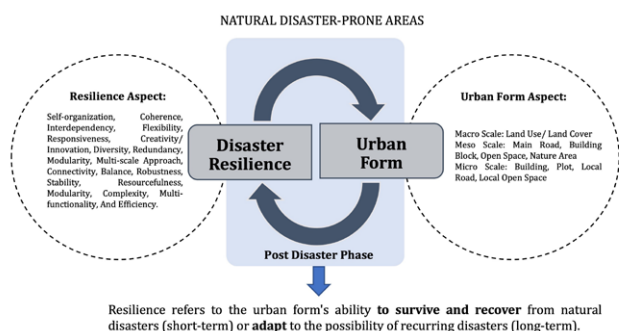


Figure 8. Aspect of resilience and urban form from the reviewed literatures (Source: Authors, 2024)

multi-scale approach connectivity, balance, robustness, stability, resourcefulness, modularity, complexity, multi-functionality, and efficiency. Based on the two aspects of resilience and urban form, the definition of urban form resilience is: the urban form’s ability to survive and recover from natural disasters (short-term) or adapt to the possibility of recurring disasters (long-term).

Limitations and recommendations from previous research

Researchers from the literature reviewed also describe the limitations they have and gaps that have become recommendations for future research (Figure 9).

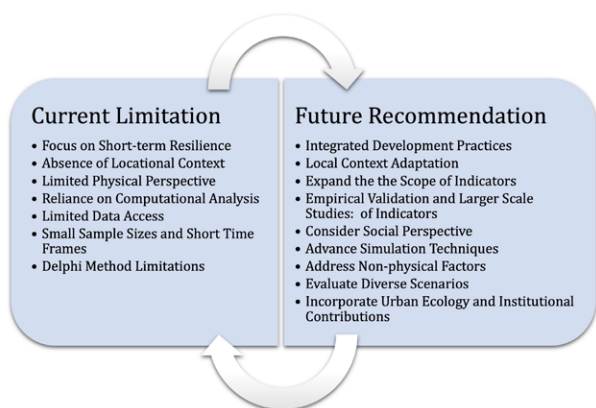


Figure 9. Limitation and recommendation from previous studies (Source: Authors, 2024)

Although current empirical research has attempted to assess the adaptation performance of urban form, the adaptation evaluated is typically in the short term after disasters through adjustments made to return to the initial conditions. Most studies, primarily theoretical, lack the location context and focus solely on the physical elements of the city without addressing societal perspectives. Some research assessing the resilience of urban form to natural disaster scenarios through simulation also lacks the consideration of social aspects and relies solely on computational analysis results. On the other hand, there are studies limited by inaccessible data, possibly due to confidentiality concerns. Additionally, some studies may be biased due to the subjective nature of the Delphi method. Furthermore, research with small sample sizes may lead to results that do not adequately represent

the population. Therefore, the future recommendations indicated in Figure 9, such as considering non-physical factors and social perspectives in resilience assessments, are efforts to address the limitations of previous research.

DISCUSSION

The evolving research topics over the past five years represent current trends under investigation. It is conceivable that these topics will continue to be developed or that new research topics will emerge in the future. The research results also indicate the most contributing authors, providing an opportunity for further research and discussion with them as experts, or for potential research collaboration. Furthermore, journals that have published extensively on urban form resilience can serve as publication venues for researchers continuing this line of inquiry.

The study of urban form resilience is mostly conceptual rather than empirical. The term itself is not commonly used as a fixed term by all researchers, which is evident from the varying usage in several articles but with the same meaning, such as “resilience in urban form”, “resilience through form”, “resilient urban form”, or “physical resilience of urban form”. The literature focuses on the strength or capability of each urban form component to survive and recover post-disaster, as well as the evacuation system utilizing roads and open spaces. This is evident from mentions of “connectivity” and “network” related to disaster resilience. The road elements are not only seen in their general transportation function, but are also considered as evacuation routes. The same applies to built-up areas, where the selection of building locations, including shelters, takes into account the scale of potential disasters.

Based on the limitations and recommendations from previous literature, there are many research opportunities in the discussion of resilience in urban form (Figure 10). In the morphological approach to urban form and its relationship with resilience criteria, there is still a tendency to discuss the topic generally and conceptually, especially in terms of research locations. Consequently, there are numerous unexplored research opportunities related to urban form resilience. For instance, the correlation between physical and non-physical factors of urban form in enhancing disaster resilience could be further investigated. The physicality of a city is shaped by human activities within it; to comprehend this, the role of a morphological approach is essential. Each place has its own character influenced by local socio-cultural aspects such as beliefs, which can serve as the foundation for community-driven urban spatial formation. Therefore, in the context of urban form resilience, non-physical aspects intersect in efforts to enhance resilience (Kropf, 2017; Oliveira, 2016).

Furthermore, there is an opportunity to delve deeper into integrating all urban form components, so that resilience does not rely solely on one component but involves support from multiple facets. Enhancing the quality of the arrangements of urban form components serves to improve the adaptive capacity, as demonstrated in research using urban design strategies. With better adaptation, resilience in facing disasters would increase. If a city demonstrates improved adaptive capabilities to disasters, it means that in the event of recurring disasters, the city is expected to

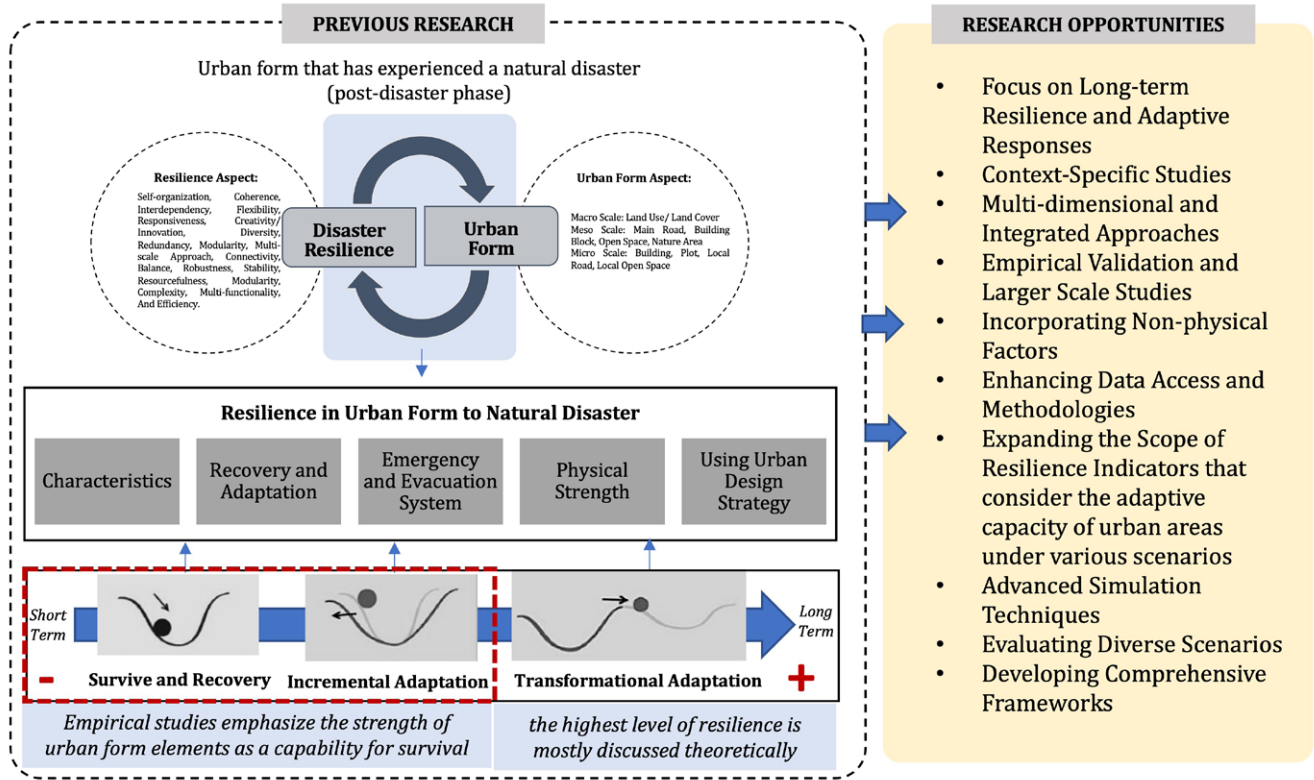


Figure 10. Research directives based on aspects of resilience in urban form (Source: Authors, 2024)

sustain independent functionality across all dimensions (Felicetti *et al.*, 2016). The lowest level of resilience is indicated by the system’s ability to survive and recover. The second is incremental adaptation, which represents a higher resilience level through adjustments using familiar methods in that place. The most theoretically distinguished is transformational adaptation, understood as the ability to adapt to disasters by innovatively changing the system using new, unfamiliar measures (Masnavi *et al.*, 2019).

Increasing urbanization, which affects city formation, cannot be avoided, so the urban form will continue to experience dynamics over time (Senjana *et al.*, 2023). Unpredictable disasters can reduce a city’s resilience, causing losses to the humans and ecosystems that inhabit the city. Relocating urban residents to a new environment does not necessarily reduce their vulnerability; instead, it creates new problems as they will be exposed to other disturbances. Therefore, another research opportunity is that urban form resilience needs to consider other dimensions besides physical ones, as they will be affected when natural disasters occur, such as social, economic, institutional, and environmental dimensions. The impact on health also ultimately affects public health, for example, the health impact of mud-related disasters (WHO, 2010a; 2010b). Therefore, adequate city planning to enhance resilience is positively correlated with public health benefits (WHO, 2022). The impact on health is not only physical but also psychological, as evidenced by the level of happiness among local residents (Salama *et al.*, 2024; World Health Organization. Regional Office for Europe (2018), WHO EHCN, 2019; Wright *et al.*, 2019).

The recommendations emerging from this review are expected to provide new knowledge to guide the resilience of urban form components to the highest level. Another aspect mentioned is collaboration with the community regarding their assessment of the city’s development where they live, especially in Global South as the most researched area. Numerous countries around the world are situated in disaster-prone locations, particularly facing natural disasters in coastal cities. Therefore, regardless of the current developmental status of an area, the concept of resilience in urban planning and spatial design is crucial and should be integrated into the operational process. Additionally, the integration of components across various scales is also urgent for research. Long-term thinking on transformational adaptation drives the need for more empirical studies, not just theoretical ones.

CONCLUSION

This study is a literature review that has investigated resilience in urban form in the context of facing natural disasters, encompassing both theoretical and empirical studies. The aim of the research is to analyze which aspects of resilience and urban form can enhance resilience and to identify opportunities or gaps in these studies that can be addressed in future research. The review reveals that the most recently studied trend relates to physical resilience and the strength characteristics of urban form components. The development of the reviewed studies has evolved from discussing urban morphology and resilience concepts in various forms, such as surviving and recovery, incremental adaptation, and transformational adaptation.

The emerging topics in the last five years include:

- characteristics of resilience in urban form;
- performance of recovery and adaptation of urban form in disaster-prone areas;
- urban form for emergency and evacuation systems,
- physical strength of urban form; and
- urban design strategies for enhancing urban form resilience.

However, despite the increase in studies, there are still limited opportunities for other researchers to continue exploring these topics, especially in the effort to create resilient cities against future natural disasters. Cities that have already achieved resilience demonstrate the capability of their systems' functions to continue operating even if disasters recur.

There are limitations in this review process, specifically the keywords, which are a recommendation for future research to use specific keywords related to types of natural disasters and components of urban form that can be analyzed according to the context of the location and disaster. Combining methods when reviewing literature can also enrich the research findings. Additional investigations are necessary to test the concept of urban form resilience in empirical research, particularly in disaster-prone developing countries, through targeted location-based studies. On the other hand, this study is the initial phase of a bigger research map that we intend to pursue. Nevertheless, this study is expected not only to assist us in progressing to the next research stages, but also to aid stakeholders as a consideration in the process of planning and developing disaster-resilient cities.

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