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Review

Disentangling the Relationship between Urban Form and Urban Resilience: A Systematic Literature Review

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Abstract: The concept of resilience was only recently introduced into urban studies to address the complexity and future uncertainty in cities. In particular, the interest in better understanding how it can be integrated into studying urban form—as the raw material of urban planning/design and key for the sustainability of cities—has been growing. However, resilience is a polysemic concept with different meanings/interpretations, which creates ambiguity and challenges in its operationalization. This paper resolves this issue through a systematic review of 106 peer-reviewed publications guided by recurring questions in the literature (e.g., resilience of/through what? To what? For whom? How? When? Where?). The results showed that the urban form–resilience relationship is complex, where many urban form elements can influence resilience to a great many disturbances (general/specified). In facing these disturbances, urban form exhibits different performances (i.e., persistence, adaptability and transformability) and where it can be either persistent/adaptable/transformable itself or can enhance people's persistence/adaptation capacities. The review also showed that there are many actors for urban form resilience and potential trade-offs. Finally, an overview of existing definitions of urban form resilience is provided to improve clarity in the field, and examples of general urban planning/design recommendations were formulated to enhance the resilience of different urban form elements.

Keywords: urban morphology; urban studies; sustainable cities; resilient built environment

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1. Introduction

Cities occupy only 3% of the Earth's land; however, in 2018 they were home to more than 55% of the world's population (around 4.2 billion people) with expectations to reach around 70% by 2050 [1]. As a result, cities, especially in developing countries where 86% of the world's urban population is expected to be living by 2050 [1], are facing unprecedented pressing challenges and have become more prone than ever to various chronic stresses and acute shocks. These include, for instance, high unemployment, lack of affordable housing, poor air quality, food shortages, water scarcity, inefficient infrastructure and transport systems, disease outbreaks, heatwaves and flooding.

To address these challenges, there is a need for new models of governance and innovative approaches to the planning and design of cities [2]. In particular, in the fields of urban planning and design, several models and approaches have been proposed since the 1980s to provide patterns of urban development and growth that are socially, economically and environmentally sustainable [3]. They include, for instance: the compact city [4]; the polycentric city [5]; the eco-neighborhood [6]; the urban village [7]; smart growth [8]; the sustainable urban neighborhood [9]; transit-oriented development [10,11]; and the new urbanism development [12,13].

More recently, the concept of resilience, defined as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" [14] (p. 86), has become mainstream in urban research and policy to prepare cities for the future uncertainty and indeterminism in "a world of transformations" [15] and contribute to the broader sustainable development goals [16–18].

This new way of resilience thinking has been widely adopted and promoted by many national and supernational organizations and was integrated into global policy documents such as the UN 2030 Agenda for Sustainable Development, specifically Goals 9 (industry, innovation and infrastructure) and 11 (sustainable cities and communities), and the New Urban Agenda, adopted by Habitat III in Quito, Ecuador. Moreover, many authoritative reports have been published by reputable organizations, such as the Urban Climate Change Research Network (UCCRN) [19], the World Bank [20] and the Intergovernmental Panel on Climate Change (IPCC) [21], to support the implementation of these policies and provide insights and guidance on building urban resilience in cities. In addition to policy and reports, several international initiatives have been promoted to support cities worldwide in integrating resilience thinking into planning and design practices [22]. Examples of these initiatives include the Making Cities Resilient (MCR) campaign by the United Nations Office for Disaster Risk Reduction (UNDRR) and the 100 Resilient Cities (100RC) program launched in 2013 by the Rockefeller Foundation.

In fact, the concept of resilience has been introduced in urban studies almost two decades ago, and since then there have been several efforts to better integrate the concept into the theory and practice of urban planning and design [23,24]. In particular, the interest in better understanding how resilience thinking can be integrated into the study of urban form (hereinafter referred to as the field of urban morphology [25]) has been growing, and several studies have been published to investigate and better establish the urban form–resilience relationship (e.g., [23,26–32]). This is because, on the one hand, urban form is regarded as the raw material of urban planning and design [33]. It refers to "the main physical elements that structure and shape the city" [25] (p. 2). These main physical elements, which "are related to each other in a hierarchy" [34] (p. 44) and can be aggregated to form higher-level elements, are the buildings, the plots and the streets [35]. Moreover, urban form extends to include non-physical or form-related features, such as density and accessibility, which also play a crucial role in defining the overall character and layout of the city [36–38]. On the other hand, several studies have shown that urban form has various impacts on the social [39], economic [40], environmental [41] and energy [42] performance of cities, and hence it is key for their sustainability [4,13,28,30,43].

However, resilience is a polysemic concept [44–46] and can be interpreted in a multitude of ways [47–49]. For example, as persistence/robustness to maintain the system's status quo against a disturbance (i.e., engineering resilience) but also as the ability of the system to incrementally adapt (i.e., ecological resilience) or more radically transform into a new equilibrium status (i.e., evolutionary resilience). Hence, there is a "need to examine the underlying politics of resilience" [16] (p. 6) and adjust its meaning "depending on the specific research question(s)" [28] (p. 168) so that it can be effectively operationalized. This requires thinking critically through a set of relevant Wh-questions (i.e., interrogatives formed using, e.g., "what", "who", "how", "where" and "when") [16,50–52]. More specifically, in urban morphology, this requires asking what elements of urban form (e.g., buildings, plots, streets, blocks) can be resilient (or can provide resilience) to what (e.g., effects of climate change, natural disasters, disease outbreaks, terrorism)? Who benefits/loses from this resilience (e.g., general or specified populations)? Who determines (plans/designs for) the resilience (e.g., policymakers, urban planners, urban designers)? And how or by which mechanism (e.g., by maintaining the system's status quo, incrementally adapting or radically transforming)? Where (in which geographical context)? And when (in the short term or long term)? However, to date, there has been little effort to understand these aforementioned politics of resilience in urban morphology and improve clarity and intelligibility in the field

about this emerging research topic. This paper aims to address this main research problem through a comprehensive systematic review of the extensive existing literature on the topic.

The remainder of this paper is organized as follows. Firstly, the review method is presented in Section 2. Then, in Section 3, a synthesis of the review results is given and these results and their implications as well as the limitations of the review are discussed in Section 4. And, finally, Section 5 presents the conclusions of this review.

2. Review Method

The systematic literature review includes three main steps (Figure 1):

1. Searching scientific databases, using relevant search terms, to retrieve potentially eligible publications for the review.
2. Excluding irrelevant publications using clearly defined inclusion/exclusion criteria and conducting a preliminary bibliometric analysis.
3. The reading and analysis of the full publications guided by specific review questions.

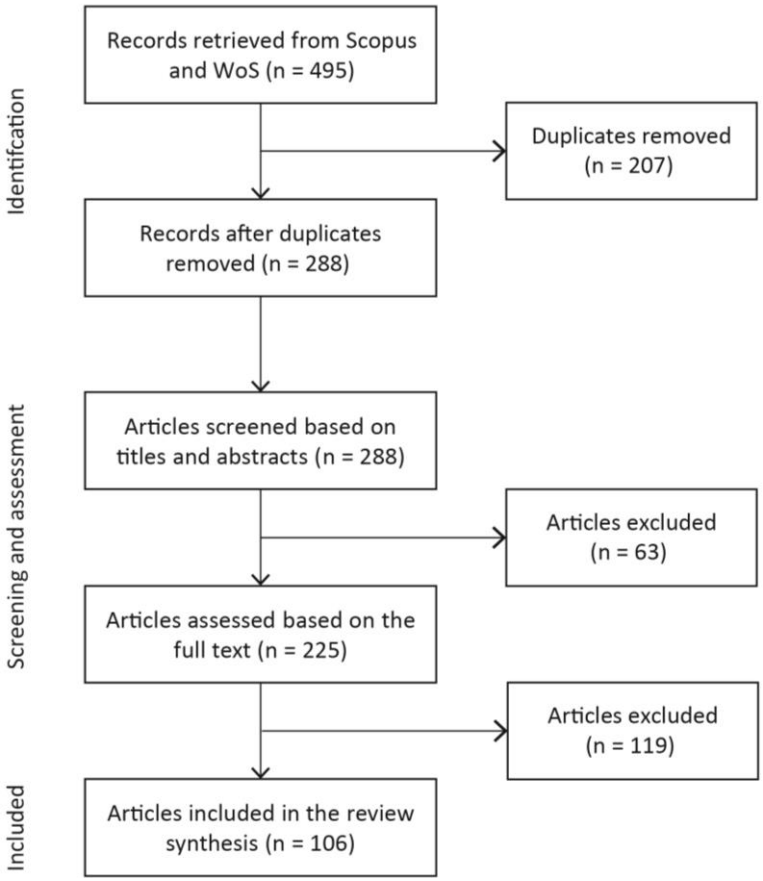

Figure 1. Flow diagram of the systematic review process.

2.1. Search Strategy and Data Extraction

To retrieve relevant peer-reviewed publications eligible for the systematic review and analysis, we conducted searches on two scientific databases, i.e., Scopus and Thompson Reuters Web of Science (WoS). Our search strategy involved a combination of relevant search terms related to urban environments (e.g., city, built, urban) and their morphology (e.g., form, fabric, tissue, geometry). In addition to these terms, we also incorporated variations of the term "resilience" (e.g., resilience, resiliency, resilient) in our searches to specifically target studies focused on this topic (see Table S1 for the complete search blocks used, Supplementary Materials). The search was restricted to peer-reviewed publications written in English and published between database inception and 31 July 2021. However, given that systematic reviews require substantial time (between six and 18 months) and

effort [53], additional relevant publications may have been published on this rapidly growing research topic since the completion of the initial search. This limitation is explicitly acknowledged in Section 4 of this paper. The initial search using the search blocks shown in Table S1 (Supplementary Materials) yielded 278 and 217 publications in Scopus and WoS, respectively, which when combined resulted in a total of 288 unique publications after excluding duplicates (207 publications).

2.2. Study Selection and Bibliometrics

As a next step, the titles and abstracts of the 288 retrieved publications were screened on a case-by-case basis to exclude obviously irrelevant publications based on the criteria of the topic relevance and the type of study. Publications were only included if they were found to discuss a physical dimension of the city in relation to a resilience principle to face a disturbance. Resilience principles can refer to either a range of different responses that a resilient system is able to implement when facing a disturbance, such as persistence, adaptability and transformability, or to a set of general qualities that the system possesses, such as redundancy, diversity and flexibility. Feliciotti [54] coined these as resilience performances and resilience attributes, respectively (see, e.g., [55–57] for a detailed description of these principles). Furthermore, only primary literature (e.g., research papers, method papers, theory papers, case studies, viewpoint/commentary papers) was included in this systematic review and secondary sources, such as narrative reviews, systematic reviews and meta-analyses that are based on original research publications, were excluded to avoid biases from the authors' perspectives or the studies they chose to include. This step reduced the number of publications to be fully read and assessed to 225 (63 publications were excluded). Finally, after reading these 225 publications another 119 publications, which did not meet the aforementioned criteria, were excluded. Therefore, the results presented in Section 3 are based on a sample of 106 publications.

Furthermore, in order to provide a preliminary analysis of the 106 included publications and to identify the different research themes (or clusters) on the topic, the bibliometric information, specifically the authors' keywords retrieved from Scopus and WoS databases, was analyzed using the VOSviewer software [58] to develop a visual representation of the most common keywords (based on their occurrence/co-occurrence in titles, abstracts and keywords). The resulting visualization is a distance-based map with clustered, colored keywords of different sizes indicating the density of their occurrence in all publications. The line between two keywords refers to their co-occurrence and the thickness of the line indicates the density of this co-occurrence. Keywords are clustered based on their co-occurrence frequencies. For this analysis, we only considered keywords that occurred at least 10 times.

2.3. Review Questions

To clarify the core meaning of resilience in urban morphology and understand how the relationship between urban form and urban resilience is addressed across the different fields and studies, the 106 included publications were fully read in an attempt to answer a number of relevant and recurring questions in the resilience literature [16,51,52,59]. These are:

1. What elements of urban form are discussed as being resilient or can enhance resilience? In this regard, we made a distinction between resilience through and of urban form. By resilience through urban form, we mean that urban form is addressed as a vehicle for resilience performance either by enhancing people's persistence during a disturbance (e.g., providing direct protection from extreme heat) (i.e., people persist) or by providing them with adaptation opportunities to maintain basic functions both during and after a disturbance, such as providing access to basic services after a flood or an earthquake (i.e., people adapt). According to Masnavi et al. [60], one can call this a "non-structured" resilience performance aiming at "creating a system that offers behavioral adaptation of people to change" (p. 10). On the other hand, the resilience of urban form means that urban form is addressed as being resilient in itself, i.e., ex-

hibiting a "structured resilience" performance [60] either by (1) being persistent (e.g., earthquake-/flood-proof buildings) (i.e., urban form persists); (2) being adaptable without experiencing major physical changes to maintain the existence of function (e.g., spaces whose design can be adapted to house temporary and emergency shelters) (i.e., urban form adapts); or (3) behaving as a complex adaptive system that is capable of accommodating "minor but continuous adjustments" [61] (p. 2) over space and time to adapt to the ever-changing conditions (e.g., societal, economic, cultural, technological) (i.e., urban form transforms/changes).

2. Resilience to what? For this question, we distinguished between the so-called general and specified (or targeted) resilience. According to Folke et al. [62], general resilience refers to the "resilience of any and all parts of a system to all kinds of shocks, including novel ones" (p. 3), whereas specified resilience refers to the "resilience of some particular part of a system . . . to one or more identified kinds of shocks" (p. 3). The different specified disturbances that were discussed in the literature in relation to urban form were identified.
3. Who are the different actors involved in the planning process of resilience? Who takes part in determining what is desirable for an urban system?
4. Resilience for whom? Or whose resilience is addressed/prioritized? Or who benefits/loses from this resilience?
5. What is the resilience performance discussed (or the pathway toward a resilient state)? For this question, we distinguished between three key different resilience performances that are widely discussed in the literature and were outlined briefly in Section 1. These are (1) persistence, to maintain the efficiency of function or a system's status quo (i.e., to bounce back) in correspondence with the engineering understanding of resilience and where there is a collapse point after which the system breaks down [63,64]; (2) adaptability (transition), to maintain the existence of key functions (i.e., to bounce forward) by incrementally changing, and which corresponds to the ecological understanding of resilience [64,65]. As discussed above, adaptability can either be a characteristic of the urban form itself (i.e., urban form adapts) or an opportunity that urban form offers to people (i.e., people adapt); and (3) transformability, to maintain the system's ability to radically change or transform (i.e., to transform forward). Transformability reflects the resilience performance of social–ecological systems (also known as evolutionary or progressive resilience) [52,66,67].
6. Resilience for when? In this review, we distinguished between resilience to short-term disruptions that usually have a short duration and are caused by rapid-onset events (or shocks) such as earthquakes and long-term disruptions with a longer duration that are caused by slow-onset events (or stresses) such as the temperature or precipitation changes caused by climate change.
7. Resilience for where? Although this question is usually addressed in the resilience literature to understand "the spatial boundaries of the urban system" [47] (p. 4) and "how fostering resilience at one spatial scale affects those at others" [16] (p. 11), our interest here is to understand where research on the topic is most active or in which contexts there is more acknowledgment and attention to the relationship between urban form and urban resilience.
8. Is resilience being discussed/defined as a positive concept? This is an important question because although there is consensus "that resilience is a positive trait that contributes to sustainability" [68] (p. 166), some argue whether it should be always perceived as such [47,69,70]. For instance, when the original state of the system is unfavorable (e.g., poverty, dictatorships), then a resilient state can be "self-defeating" [47,71].
9. Did the author(s) explicitly/implicitly define what urban form resilience is or what resilient urban forms are? Agreeing on a common definition of urban form resilience is an important step to operationalizing resilience in urban morphology and preventing it from becoming an "empty signifier" [16,47,59]. Therefore, this question aims to

provide an understanding of how the combination of urban form and urban resilience is defined across different fields and studies.

3. Synthesis of the Review Results

This section provides a synthesis of the review results. The section is organized as follows: firstly, the results of the bibliometric analysis of the 106 included publications are presented in Section 3.1; then, in Section 3.2 the answer to each of the review questions put forward in Section 2.3 is provided based on the systematic reading of the 106 selected publications; and finally, a selection of definitions of urban form resilience (or resilient urban forms) that were identified in the reviewed publications is provided and categorized in Section 3.3.

3.1. Bibliometrics

Figure 2 shows the network of keywords' occurrence/co-occurrence based on the 106 included publications from Scopus and WoS. Four clusters of keywords were formed based on their co-occurrence frequencies. These clusters represent different research themes on the topic of urban form and urban resilience: Cluster 1 (in blue) focuses on urban resilience and urban planning and their relation to other broader topics like sustainability and governance; Cluster 2 (in red) focuses mainly on the interconnected aspects of the built environment, resilience and sustainable development, as well as on risk assessment/management; Cluster 3 (in green) takes more of an urban design and morphology perspective and focuses on the urban form of cities and neighborhoods as well as on urban population (or humans); and Cluster 4 (in yellow) focuses on climate change, atmospheric temperature and the urban heat island (UHI) effect.

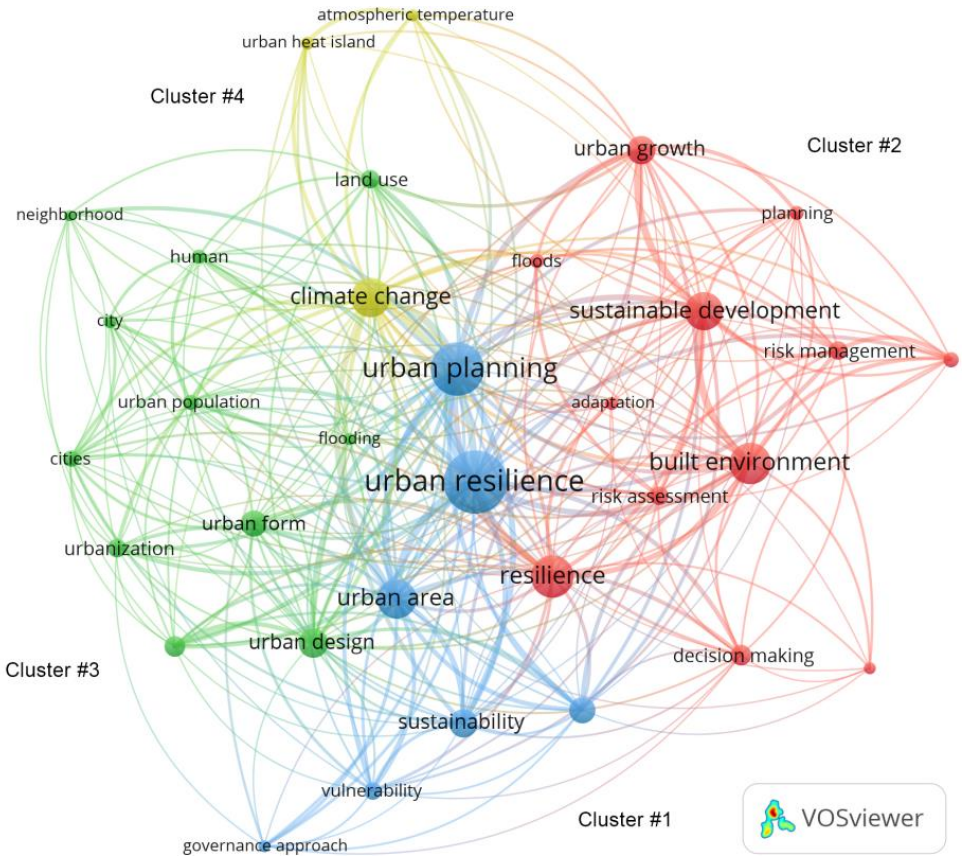

Figure 2. The network of keywords' occurrence/co-occurrence formed using the VOSviewer software (version 1.6.17) based on the 106 included publications from Scopus and WoS.

3.2. The Underlying Politics of Resilience in Urban Morphology

3.2.1. Resilience of What or through What?

The review of the 106 included publications has shown that there are at least 11 urban form elements that can enhance urban resilience to different stresses and shocks (Table 1). In this section, we give an overview of these elements, and in Section 3.2.2, we further associate them with specific stresses and shocks.

Table 1. The urban form elements that were discussed in the reviewed literature in relation to resilience performances and/or attributes to face general/specified disturbances. Elements followed by an asterisk refer to urban form elements formed by aggregating lower-scale elements.

Scale	Urban Form Element	Number of Publications			
		Through	Of	Through and Of	Total
Macro-scale	The whole built environment	13	5	1	19
	Development type	11	5	1	17
Meso-to-micro-scale	Building	8	6	-	14
	Open/Green space	12	1	-	13
	Neighborhood/Sanctuary area *	7	1	-	8
	Street	5	-	-	5
	Land use *	3	-	-	3
	Block *	2	-	-	2
	The urban project *	1	1	-	2
	Underground space	1	-	-	1
	Plot	-	1	-	1
Varied		13	6	2	21
Total		76	26	4	106

In general, one can address these urban form elements at three main scales following a hierarchical approach as suggested by Sharifi and Yamagata [28], namely the macro-, meso- and micro-scales. The hierarchical approach for classifying urban form elements characterizes the work of the Italian school in urban morphology. It emphasizes that urban form constituents are hierarchically organized in a part-to-whole relationship, with elements at lower levels, such as plots and streets, being aggregated to form structures, such as blocks (aggregates of elements); systems, such as neighborhoods or urban tissues (aggregates of structures); and organisms, such as cities (aggregates of systems) [27,34,72,73]. In particular, at the macro-scale, "urban form concerns the whole structure of the city, its existing position, and its future development in relation to other cities and settlements in the broader network of cities and city regions" [28] (p. 170). On the other hand, at the meso- and micro-scales, urban form concerns, respectively, "the general structure of neighborhoods and districts" [28] (p. 173) and "the structure of buildings, how they are located in relation to each other (on the site), and their relative position with respect to the pedestrian and traffic networks in a finer level of granularity" [28] (p. 174). Table 1 lists these different-scale urban form elements and indicates whether they are discussed in the literature as being resilient in themselves (i.e., resilience of urban form) or as means for providing resilience to people to face different disturbances (i.e., resilience through urban form).

More specifically, around 34% of publications (36) focused on the macro-scale level of urban form by addressing either the built environment as a whole (19 publications) or the type of urban development, for instance, in terms of the growth pattern (e.g., compact versus dispersed or planned versus informal); shape (star, hexagonal, rectangular); and type of clustering (e.g., polycentric versus monocentric) (17 publications).

On the other hand, around 46% of the publications (49) focused on the meso-to-micro-scale level of urban form. Within this level, buildings (14), open/green spaces (13) and neighborhoods or sanctuary areas (i.e., assemblages of meso-/micro-scale urban form elements such as buildings, plots, streets and blocks [54]) (8) were the most discussed urban form elements in relation to resilience performances and/or attributes. The latter concept of sanctuary areas was introduced in 1980 by Appleyard [74] and is similar, in principle, to the "plan unit" of Conzen [35] and the "*tessuto urbano*" of Caniggia and Maffei [73]. Four meso-to-micro-scale urban form elements were discussed in the literature more than once but not more than five times. These include streets (5), land uses (3), blocks (2) and the so-called urban project (2). The latter refers to the form of urban projects that are not built based on a rigid and prohibitive set of rules and regulations, such as those typically found in flood-risk prevention plans, but rather with a certain degree of flexibility and attention to local contexts that can enhance urban resilience [75,76]. There are two urban form elements that were discussed only once in the reviewed literature, namely the underground space (or the subsurface) and the plot. The remaining 21 publications (20%) discussed a combination of the aforementioned urban form elements. These are marked as "varied" in Table 1.

As for the distinction between resilience through and of urban form, Table 1 and Figure 3 show that the large majority (72%) of publications (76) addressed providing resilience through urban form, where almost all the urban form elements were involved. On the other hand, 26 publications (24%) discussed the resilience of the urban form elements themselves with a focus on buildings, development types and the built environment as a whole. There are only four publications (4%) that discussed both resilience through and of urban form, as they discussed a variety of urban form elements that can contribute to resilience via both mechanisms.

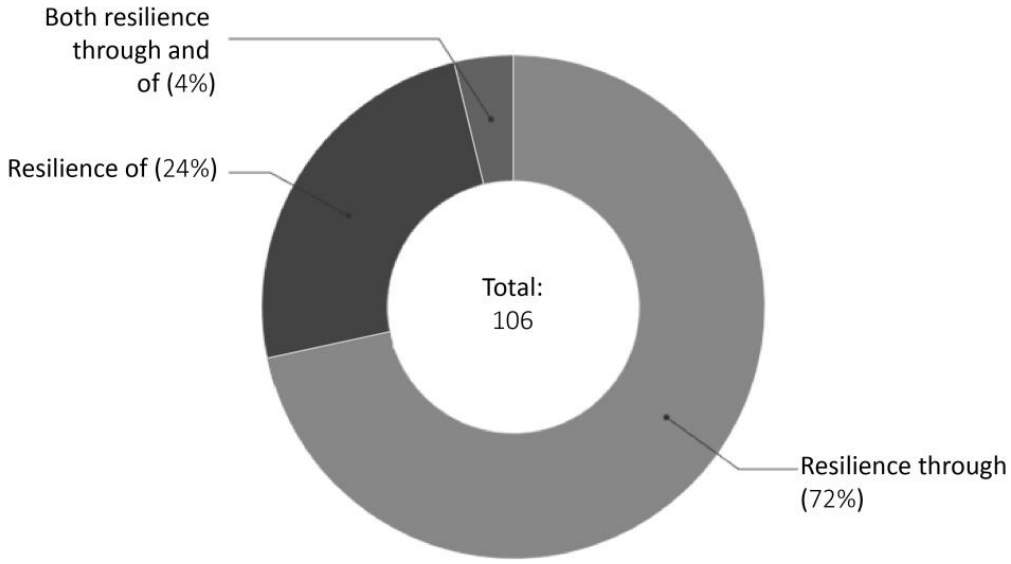

Figure 3. The distribution of the reviewed publications based on the distinction between resilience through and of urban form.

3.2.2. Resilience to What?

Regarding the type of stresses and shocks that the urban form elements, discussed in the previous section, can provide resilience to, the review has shown that there are a great many. In general, the large majority (86%) of the publications (91) discussed resilience to a specific disturbance, while only 15 publications (14%) discussed resilience to general unforeseen disturbances (Figure 4).

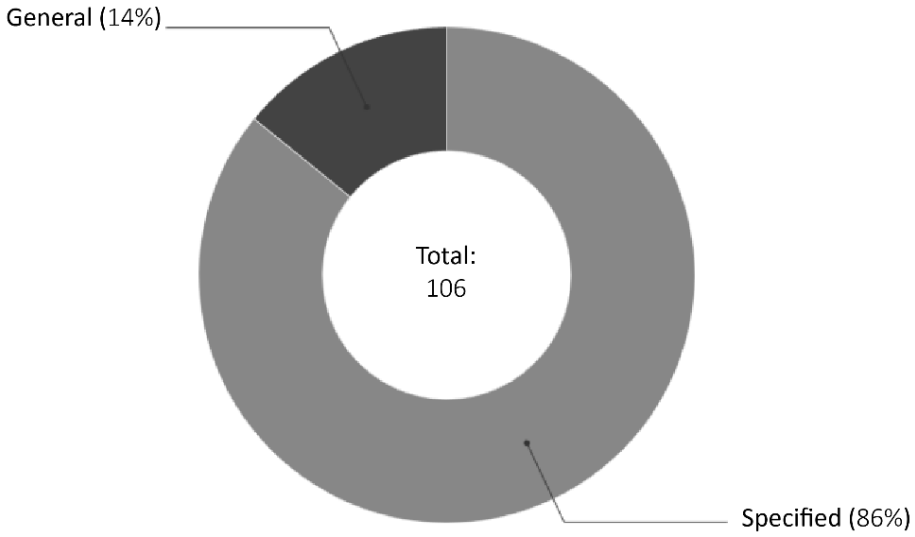

Figure 4. The distribution of the reviewed publications based on the type of resilience they discuss (general versus specified).

More specifically, there are at least 17 different types of stresses and shocks that urban form elements can provide resilience to, where floods (22), earthquakes (15) and high temperatures (10) are the most discussed disturbances in the literature in relation to urban form. And disturbances such as terrorist attacks, ill-being, warfare/armed conflicts, water scarcity and gentrification are the least discussed ones with only one publication addressing each. Table S2 in the Supplementary Materials shows the full list of these stresses and shocks as well as the urban form elements that are associated with each. They are discussed below in more detail.

Floods, Earthquakes and Related General Structural Collapses

Twenty-two and fifteen of the reviewed publications focused on resilience to floods and earthquakes, respectively, where, in most cases, they were discussed in relation to three specific urban form elements, namely the type of development, buildings and open/green spaces.

On the one hand, it was found that compact growth patterns of urban development (also known as smart growth) can lead to an overall reduction, at the city scale, in flood losses compared to low-density urban sprawls [77,78]. This can be related to the concentration of urban development in the most suitable land available while avoiding flood-prone areas [79]. However, at the neighborhood scale, high-density developments can increase surface runoff due to the relatively high fraction of impervious surface cover. Therefore, one should account for this trade-off between the neighborhood and the city scales when it comes to runoff/flood mitigation [78].

On the other hand, compact developments were found to be less seismic-resilient (where polycentric compact developments are favored over monocentric ones) when compared to extreme urban sprawls. This is because in urban sprawls "only a small share of the city will be exposed to an earthquake at a time" [80] (p. 97). However, this development type is widely recognized as among the most unsustainable forms of development and is not preferred by most planners [81,82]. Also, the geometric shape of the city (e.g., rectangular, hexagonal, star, circular) was found to influence its resilience when hit by an earthquake. More specifically, Bozza et al. [83] found that star-shaped cities (e.g., the ideal Renaissance city) are the most seismic-resilient and circular-shaped ones (e.g., Rome and L'Enfant's Plan for Washington, D.C.) are the least resilient. This was assessed by measuring the degree of damage in buildings and streets as well as the level of connectivity between the different parts of the city in the aftermath of different earthquake scenarios.

As for buildings, it was found that building characteristics such as the geometry of structural elements (e.g., columns and beams) [84,85] and building heights and density [86] are key determinants of the resilience, or more precisely the persistence, of buildings to both floods and earthquakes.

Open/green spaces were also discussed in several publications as being important urban form elements for enhancing people's resilience during floods [87] and earthquakes [88], for instance, by acting as emergency evacuation directing points, temporary shelters and distribution points for essential goods and emergency medical services, among other survival needs.

Besides the many reviewed studies that focused on the relationship between urban form and resilience to floods and earthquakes, there is another study that discussed resilience to general structural collapses (e.g., because of earthquakes, floods and fires). More specifically, Cutini and Pezzica [89] discussed how the characteristics of the street network (e.g., number of connections and availability of path alternatives) can play an important role in "maintain[ing] the operation of urban functional assets by redistributing movement after a physical perturbation" (p. 2).

High Temperatures

Ten studies focused on providing resilience to extremely high temperatures through urban form. This was mainly associated with the characteristics of open/green spaces, such as the coverage of tree canopy and soft/natural landscape materials [90–93] and with the urban form characteristics of neighborhoods/sanctuary areas. The latter include, for example: the shaping, dimensions and arrangement of urban form elements such as buildings and streets; building construction materials and their properties (e.g., thermal and radiative); and land cover types (e.g., plants, bare rock, bare soil, sand) and their ephemeral properties (e.g., dry/wet ground) [94–97].

Climate Change

Eight studies focused on the relationship between urban form and resilience to various effects of climate change, where different macro- and meso-/micro-scale urban form elements were discussed. For instance, Wang and Foley [98] discussed how the proper location, design and management of urban open/green spaces (e.g., urban parks) can improve the delivery of ecosystem services (e.g., carbon sequestration, temperature reduction, water purification), thus stabilizing rapidly changing climate conditions. Dhar and Khirfan [99] discussed the potential role that the built environment, as a whole complex adaptive system, can play "to accommodate new or retrofitted forms (and/or functions) through [an] incremental transformation so as to adapt to climate change and its ensuing uncertainty [100,101]" (p. 73). Tablada and Zhao [102] showed that different block types (e.g., point block, slab block, contemporary block) can have different potentials to achieve food and energy self-sufficiency, which are at high risk because of climate change.

Energy Shortages

Five studies focused on resilience to energy shortages, which was discussed in relation to a variety of urban form elements. These include, for instance, land use, streets, buildings, blocks and development types, where Ragheb et al. [103] related each of these elements to specific energy resilience attributes (e.g., diversity, redundancy, flexibility) based on a review of different energy efficiency frameworks in urban planning. For instance, an energy-resilient city should be diverse in terms of land uses to ensure the functionality of the system in case of energy supply disruptions [56].

Disease Outbreaks

Two studies focused on the relationship between urban form and urban resilience to disease outbreaks. For instance, Lak et al. [104] pointed out that a pandemic-resilient urban form can minimize the risk of virus spread at three different scales. These are

(1) the building (e.g., by designing semi-open spaces in housings, such as balconies for planting and pleasure, and sanitation facilities shared by multiple households); (2) the neighborhood (e.g., by providing semi-public and semi-private or shared open spaces in residential buildings for planting, playing and working out in pandemic situations); and (3) the city (e.g., by creating less dense urban centers to decelerate the spread of diseases and avoiding locating cities at short distances).

Economic Recessions and Financial Crises

Two studies focused on the relationship between resilience to economic recessions or financial crises and urban form. More specifically, in the first study, Rao et al. [105] discussed how certain types of retail buildings/shops can offer, through their design such as building size and degree of land subdivision, opportunities for adaptation to shocks, such as boom–bust cycles "while fostering a viable retail economy and strong public urban life simultaneously [106]" (p. 553). For instance, financial crises can lead to underperformance, bankruptcy and the closure of retailers that possess big box stores and large land holdings under single ownerships [107,108]. In the other study, Nielsen [109] discussed how the design of the street network can facilitate access to retail concentrations, thus allowing households to "adapt their behavior and possibly reduce travel in response to the changing economic climate" (p. 10).

Immigration/Migration

Two studies discussed how the urban form of arrival cities [110] can enhance their capacity for "ingesting immigration, adapting to the on-going changes and successfully responding to the needs of immigrants" [111] (p. 768). For instance, Asikin et al. [112] showed that the spatial adaptability/flexibility of some urban form elements in Malang, Indonesia, has enhanced its resilience. This includes, for instance, streets that could be used by migrants as spaces for business and social gatherings/events (e.g., weddings) and dwelling spaces that could be easily adjusted to the lifestyle and needs of the new migrants.

Fires

Two studies discussed the relationship between urban form and resilience to fires, where the focus was primarily on buildings and their characteristics, such as heights, structure and uses, as well as their proximity to fire stations [113,114].

Urban Poverty

The relationship between resilience to the effects of urban poverty and urban form was discussed in two studies and, specifically, in relation to building characteristics. For instance, Sanders et al. [115] argued that while poverty itself cannot be eliminated, improving the quality of housing (e.g., in terms of heating and ventilation) can foster resilience to its harmful health effects. On the other hand, Avogo et al. [116] showed that the transformation of housing in Accra, Ghana, has increased the capacity of the urban poor households to survive and be more resilient to the rapidly deteriorating socio-economic conditions. This was achieved, for instance, by using newly added buildings' extensions as home-based enterprises to foster family income (e.g., retail shops, food/water vending, charcoal selling and drinking bars).

Air Pollution

Two studies focused on the relationship between resilience to air pollution and urban form, where different urban form characteristics were discussed as having an impact on outdoor air quality by influencing traffic emissions, pollutant concentrations and population exposure to air pollution. These include, for instance, built density, land use types and the roughness of the urban form elements (e.g., height/compactness of buildings) [117].

Ill-Being

According to Merriam-Webster's online dictionary, ill-being is "a condition of being deficient in health, happiness, or prosperity". There is a single study, i.e., [118], that focused on the relationship between well-being/ill-being and urban form. In this study, the configurational characteristics of open spaces, specifically their spatial integration (i.e., how close a space is to all other spaces [119]), were found to influence the diversity and connectivity of positive human experiences (e.g., calmness, escape from one's routine and nature) that contribute to people's well-being. It was found that people's well-being, or what was referred to as "resilience at eye level" (i.e., the level where people experience the city [26]), can be promoted through "a diversity of experiences and . . . [an intermediate] level of connectivity between them" [118] (p. 71).

Warfare/Armed Conflicts

One reviewed study pointed out the importance of urban form in supporting various survival practices of civilians during urban warfare. In this study, Kittana and Meulder [120] found that the spatial characteristics of the *kasbah* (i.e., the fortified quarter of an old Islamic city) of Nablus, Palestine, enabled the local residents to survive and make a living during the Israeli invasion of Nablus in 2002. More specifically, three spatial elements of the *kasbah* were discussed. These are (1) nodes such as houses, factories, mosques and other buildings that, due to their physical or spatial characteristics such as materials, size and orientation, could provide sheltering, hiding, medical care and storing facilities, as well as places for people to meet and interact, thus forming strong social bonds and a feeling of togetherness; (2) sneaks defined as "alternative routes of movement [e.g., tunnel-like streets, narrow passages, back doors] that are concealed from the Israeli fields of view" [120] (p. 709). Sneaks played an important role during the 2002 invasion because they provided civilians with opportunities for "escaping, delivering items and people, rescuing wounded people, recovering dead bodies, conveying news and communicating information" [120] (p. 710); and (3) edges, which refer to the "three-dimensional imagined lines [e.g., formed by the building's architectural features such as height and windows] that separate exposed and protected spaces [from the fields of fire]" [120] (p. 710).

Water Scarcity

A single study focused on the role of urban form, and specifically buildings, in providing resilience to water scarcity. More specifically, Paschoalin et al. [121] examined the potential of rainwater harvesting in heritage buildings in Wellington, New Zealand, where they found that roof spaces can collect a significant amount of water per year that could potentially be used, for example, for irrigation, toilet flushing and emergency water for fighting fires, thus enhancing residents' resilience to water scarcity.

Terrorist Attacks

There is only one study that referred to the potential role of urban form in combating terrorism. More specifically, Fischer et al. [122] discussed how different development patterns, such as compact and linear developments, may exhibit different degrees of susceptibility to terrorist attacks. Unsurprisingly, it was found that in compact developments, there may exist several hotspots with a relatively high susceptibility compared to the linear ones, which exhibit low susceptibility due to the clear separation between the different uses and the relatively low density.

Gentrification

There is a single study that discussed the relationship between resilience to gentrification—as a form of inevitable future change and transformation in cities—and urban form. More specifically, Venerandi et al. [123] hypothesized that "traditional, fine-grained urban forms are more capable than others of responding to small-scale, largely self-organized dynamics of socio-cultural nature, in this case, gentrification by 'collective action'" (p. 1061).

They found that there are shared urban form characteristics, especially at the unit of the street edge (i.e., "the sum total of all the plots on one block which face the same street " [123] (p. 1063)), between five neighborhoods in London, England, that have undergone a process of gentrification by collective action. These include, for instance, the area of the street edge; the centrality of the street that defines the street edge; the average height of all buildings on a street edge; and the total amount of gross floor area over the street edge area. However, this, in their words, does not imply "any causal or universal relationship between morphological and social dynamics [due to the number and size of the cases investigated, and the confinement within this study to only cases of a single-type of gentrified neighborhoods]" [123] (p. 1056).

3.2.3. Who Determines Resilience?

The review has shown that there are a great many actors who are involved in the planning and decision-making process of resilience through/of urban form. These actors have different perspectives and priorities and include, for example: urban/town planners [89,103,104,114,115,117,124–129], policymakers [89,99,104,114,117,124], urban designers [30,75,89,104,127], decisionmakers [98,103,125,128,130], architects [75,115], researchers [99], urban managers [114], coastal planners [126], landscape designers [75], politicians [117] and sociologists [126].

3.2.4. Resilience for Whom?

Most of the research carried out in the reviewed literature focused on the resilience of the general population, where terms such as society [99,117,131–143], city residents [89,91,94,144–147], community [77,98,148], ecosystem [137,149] and stakeholders [98,150] were recurrent. Examples of the specified population that was addressed in a few of the reviewed publications include: the low-income population in Accra, Ghana [116]; the Madurese migrants in Indonesia [112]; African Americans in the US [115]; the tsunami-affected communities in Sri Lanka [126]; and the local residents of Nablus, Palestine [120].

3.2.5. Pathways to Urban Resilience

Figure 5 shows that 38 out of 106 of the reviewed publications focused on the adaptability pathway to resilience, 33 focused on persistence, 18 did not take an explicit position (or are unclear), nine discussed a combination of pathways and eight focused on transformability.

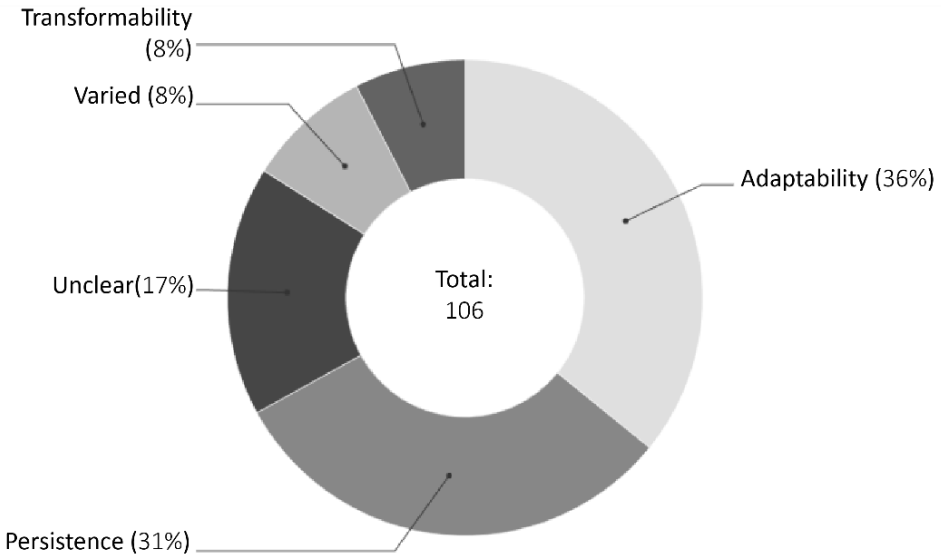

Figure 5. The distribution of the reviewed publications based on the pathway of resilience they focus on.

Adaptability (People Adapt Versus Urban form Adapts)

Thirty-four out of the thirty-eight publications on adaptability focused on the opportunities that urban form offers to people to adapt and maintain basic functions during and after a disturbance (i.e., people adapt) (Figure 6). In the reviewed literature, this was best exemplified by the capacity of the urban form elements, especially streets and open spaces, to enable people to access safe destinations after disturbances (e.g., floods and earthquakes), where they can meet survival needs such as temporary sheltering, medical care, basic goods as well as information and awareness [88,89,126,145].

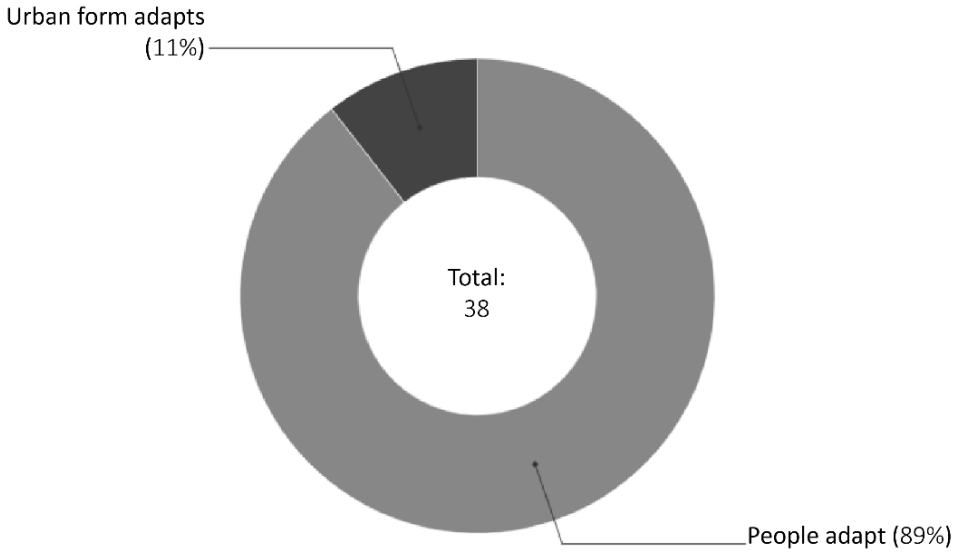

Figure 6. The distribution of the reviewed publications based on the type of adaptability performance they discuss (people adapt versus urban form adapts).

On the other hand, only four publications focused on the capacity of the urban form elements to be adapted without experiencing major physical changes to serve diverse key functions during and/or after a disturbance (i.e., urban form adapts) (Figure 6). This includes, for instance, buildings with spaces that are polyvalent/unlabeled [151], indeterminant/half-determinant/unfinished [152] or flexible. These spaces can allow new users (e.g., immigrants/migrants) to adjust and re-organize the available space to meet their lifestyle, societal and cultural needs [112] or enable existing users to add extensions that work, for example, as home-based enterprises (e.g., retail shops, selling and drinking bars) to foster family income in the time of economic crises [116].

Other typical examples of the adaptability capacity of urban form (that were not discussed in the included publications) include streets or open spaces that can be temporarily used to store stormwater runoff during flooding (by functioning as bioswales) or to house temporary and emergency shelters after disasters such as earthquakes [153–155].

Persistence (People Persist Versus Urban form Persists)

Twenty out of the thirty-three publications on persistence discussed how urban form can enhance people's persistence capacity during a disturbance (i.e., people persist) (Figure 7). In particular, half of these publications (10) focused on the role of different urban form elements (referred to in Section 3.2.1) in providing resilience to high-temperature events by keeping outdoor temperatures below what Sharifi and Boland [90] called the "critical thermal threshold" (CTT). CTT is associated with zero human activity and can lead to severe health consequences. On the other hand, 13 publications focused on the persistence of the urban form elements themselves (i.e., urban form persists) with more than half (8 out of 13) focusing on earthquake-/flood-/fire-proof buildings and development patterns.

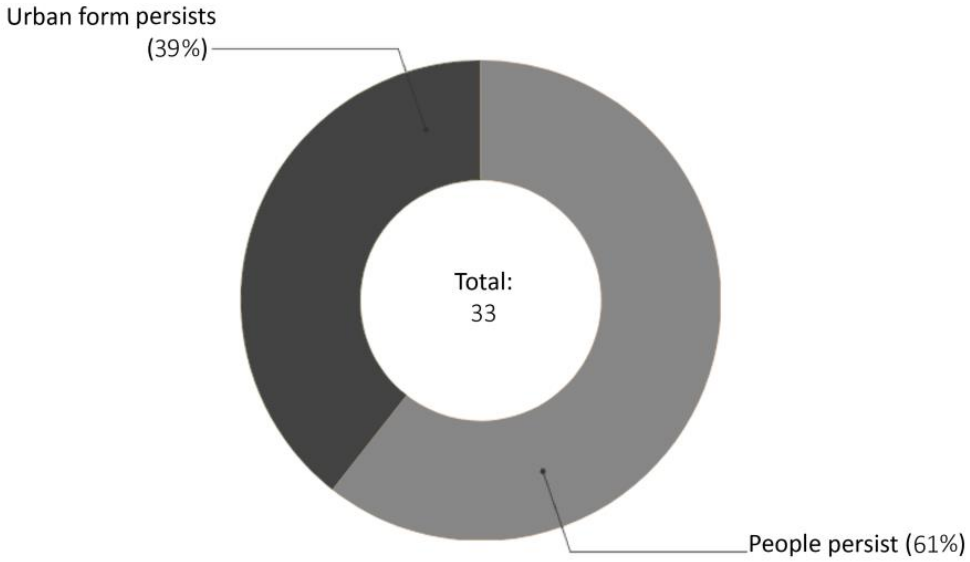

Figure 7. The distribution of the reviewed publications based on the type of persistence performance they discuss (people persist versus urban form persists).

Transformability (Urban form Transforms/Changes)

Six of the eight publications on transformability addressed resilience to general unanticipated disruptions or future unknown urban change (i.e., general resilience), while only two discussed resilience to specified disturbances, namely climate change [99] and gentrification by collective action [123]. The focus of all of these publications was primarily on the capacity of different urban form elements, such as plots [147] and open/green spaces [129], or the built environment as a whole [99,135] to behave as a complex system. Complex systems "change and evolve over time at different speed[s] and different scales" [61] (p. 3) and so does urban form with a combination of long-lasting (e.g., streets) and changeable (e.g., buildings) constituent elements; each has its own adaptive cycle at a different speed. According to Romice et al. [61], "it is this dynamic relationship between fast and slow, changeable and permanent that has always enabled cities to respond to challenges of different nature: from local fast-paced changes to large-scale events" (p. 3).

3.2.6. Resilience for When?

Figure 8 shows the distribution of the reviewed publications based on the temporal scale of resilience they discuss (as explicitly expressed by authors), where in more than half of the publications (55), authors explicitly expressed long-term resilience targets. However, only two publications explicitly expressed short-term resilience targets. In around 46% of the publications (49), the authors' points of view regarding the temporal scale of resilience discussed were not clear. Nonetheless, one can generally expect that the focus is on short-term resilience when the discussed pathway to resilience (Section 3.2.5) is through persistence, whereas long-term resilience would likely require some degree of adaptability or transformability performance [16,156]. Also, building short-term resilience is usually associated with disturbances that are rapid/sudden-onset and have a short duration (i.e., shocks), such as earthquakes and terrorist attacks, while building long-term resilience is usually associated with slow-onset events that result from incremental changes over time and have a protracted duration (i.e., stresses), such as irregular immigration/migration and changes in precipitation and temperature patterns caused by climate change.

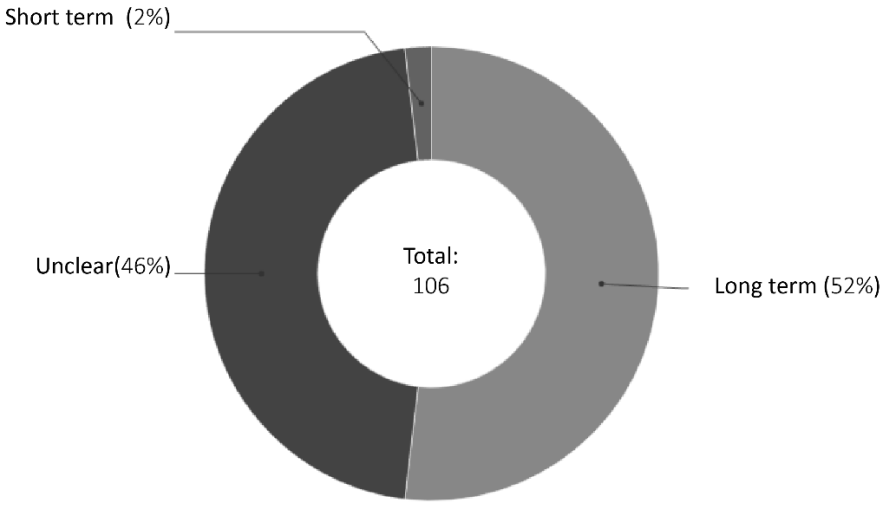

Figure 8. The distribution of the reviewed publications based on the temporal scale of resilience discussed from the authors' point of view.

3.2.7. Resilience for Where?

In general, 73 (69%) out of the 106 publications were geographically contextualized (i.e., investigated the relationship between urban form and urban resilience in a specific context). Table 2 shows these different contexts (indicating the number of publications per country). Furthermore, Table 3 shows the top most-discussed urban form elements and disturbances per continent.

Table 2. The countries where the relationship between urban form and urban resilience was discussed and studied.

Country	Number of Publications	Country	Number of Publications
Australia	7	Japan	2
Iran	7	Bangladesh	1
Italy	7	Ireland	1
France	5	Sweden	1
China	4	North Macedonia	1
UK	3	Ghana	1
Canada	3	India	1
Chile	3	Sri Lanka	1
Brazil	3	Israel and Palestine occupied territories	1
Vietnam	2	Taiwan	1
Greece	2	Indonesia	1
Spain	2	Barbados	1
Germany	2	Scotland	1
USA	2	Denmark	1
Oman	2	Singapore	1
Portugal	2	Nigeria	1

More specifically, most of these publications were in the European context (29 publications), where the top most-discussed urban form element is the type of development, and it was specifically discussed in relation to floods. On the other hand, Africa is the continent with the least number of publications on the topic with only two publications focusing on the role that different urban form elements (e.g., buildings, streets and open/green spaces) play in providing resilience to two specific disturbances, namely urban poverty and floods.

Table 3. The number of publications (per continent in descending order) focusing on the relationship between urban form and urban resilience, as well as the top most-discussed urban form elements and disturbances.

Continent	Number of Publications	The Top Most-Discussed Urban Form Element(s)	The Top Most-Discussed Disturbance(s)
Europe	29	Type of development (6)	Floods (8)
Asia	23	Type of development (6)	Earthquakes (6)
South America	7	Type of development (2) and open/green spaces (2)	Floods (5)
Australia	7	Open/Green spaces (3)	High temperatures (3)
North America	5	Neighborhood/Sanctuary areas (3)	High temperatures (3)
Africa	2	Buildings, streets and open/green spaces (2)	Urban poverty (1) and floods (1)

3.2.8. Resilience as a Positive Concept and Potential Negative Consequences and Trade-Offs of Specifically Targeted Urban Form Resilience Approaches

In general, almost all the 106 reviewed publications discussed urban form resilience as a positive concept, a desirable state, or a "politically significant notion" [71]. Nevertheless, a single study (i.e., [157]) pointed out that the planning for increased resilience (or more precisely persistence) of buildings to earthquakes may result in increased environmental impacts at the construction stage. Another study of the reviewed literature (i.e., [78]) pointed out that enhancing urban form resilience to flooding at the city scale can have negative effects at the neighborhood scale, highlighting a possible resilience trade-off. Furthermore, when urban form resilience to gentrification was viewed as a "good thing" by Venerandi et al. [123], this was because gentrification was discussed as a form of inevitable future change and transformation in cities. But what if we want to combat the negative effects of gentrification such as the forced displacement of the population? Then, an urban form that accommodates physical changes and facilitates transformation may be undesirable. However, as previously highlighted, since there is a consensus that resilience is a positive concept/trait [68,158–160], one can argue that the aforementioned potential negative consequences and trade-offs (e.g., temporal, spatial) are not inherent to the resilience idea itself. Instead, they may result from specific approaches taken or from how resilience is operationalized in practice by the different actors discussed in Section 3.2.3 (e.g., urban planners/designers, decision/policymakers, stakeholders). Typically, such approaches tend to concentrate on specific targets and/or individuals without "grappling with trade-offs and scalar complexities" [16] (p. 3). Section 4.1 highlights a few more examples of the potential negative consequences and trade-offs of such resilience approaches. According to Brown ([50], as cited in [16], p. 5), "part of the problem has to do with the transference of an ecological concept (i.e., resilient ecosystems) to social systems, at least initially by scholars not especially familiar with complexities associated with studying how society functions".

3.3. Existing Definitions of Urban Form Resilience (or Resilient Urban Forms)

Out of the 106 reviewed publications, only 31 (29%) explicitly/implicitly defined (or used other scholars' definitions of) urban form resilience or resilient urban forms. In this section, we have compiled these definitions which can be broadly classified into two categories: general definitions (Table 4) that focus on resilience to ever-changing conditions (e.g., socio-economic, cultural, demographic and technological) or to general unforeseen disturbances; and specific definitions (Table 5) that focus on certain stresses/shocks and/or urban form elements. The general definitions were further organized based on the different types of resilience interpretations/approaches presented previously. These included ecological approaches that focus on incremental adaptation (transition) and evolutionary/social–ecological approaches that focus on transformation as mechanisms of change. Definitions

that lacked clarity regarding the mechanism of change are marked as "unclear" in the table. Furthermore, to identify common concepts among the general definitions, we have listed in Table 4 the resilience principles (i.e., performances and attributes, discussed in Section 2.2) addressed in each.

Table 4. A selection of general definitions of urban form resilience (or resilient urban form) identified in the 106 reviewed publications.

Resilience Approach	Definition	Resilience Principle(s)	Source
Ecological	"... facilitates recovery after disasters and increases the adaptive capacity of the urban system with a degree of shock absorption" (p. 312).	Absorption, adaptability, recovery	[29], as cited in [161]
	"... provide[s] diversity of options and resources for recovery, flexibility to adapt to changed conditions and new functions ..." (p. 1368).	Adaptability, diversity, flexibility, recovery	[127]
	"... adapt[s] to fluctuating economic, environmental and social circumstances [due] to the dynamic interplay between [its fundamental] scales [namely, plots, street edges, blocks, streets and sanctuary areas/districts]" (p. 25).	Adaptability, scaling/nestedness	[30]
	"... the capacity of the form of the physical city to adapt to everchanging social, economic, and technical contexts" (p. 593).	Adaptability	[162]
	"... the capacity of the physical city to avoid obsolescence (often even early obsolescence) through self-organized processes of adaptation to change" (p. 594).	Adaptability, self-organization	
	"... enable[s] and support[s] a virtuous cycle of gradual investment, capable of meeting changing human needs over time in a flexible and responsive manner" (p. 20).	Flexibility, responsiveness	[147]
Evolutionary/ Social–ecological	"... accommodate[s] new or retrofitted forms (and/or functions) through incremental transformation so as to adapt to climate change and its ensuing uncertainty ..." (p. 73).	Adaptability, transformability	[99]
	"... [reduces] shocks ... facilitate[s] incremental and generative urban development ... [and] strengthen[s] the innate ability of the urban system to be transformed physically, functionally, and spatially in a manner that accommodates new changes in society, economy, and/or environment over time" (p. 81).	Transformability	
	"... accommodate[s] adaptation through incremental changes that facilitate transformation and diversity.... These adaptations cannot be satisfactorily implemented at a single scale. Rather, they form part of a hierarchical continuum of interacting systems (for example, metropolis, neighbourhood and street) that adapt at different rates and require a variety of approaches to facilitate improved resilience" (pp. 183–184).	Adaptability, diversity, scaling/nestedness, transformability	[135]

Table 4. *Cont.*

Resilience Approach	Definition	Resilience Principle(s)	Source
	"... the ability of the city's physical forms to adapt and transform in the presence of urban change, without requiring heavy operations, such as the destruction and reconstruction of entire neighbourhoods" (p. 594).	Adaptability, transformability	[162]
	"... the potential adaptability and transformability (or, conversely, with the potential fragility) of the present forms of the physical city when confronted with future socioeconomic and technical changes that urban societies constantly produce endogenously ... for example, in lifestyles, work organization, and use of technology, in the urban space" (p. 594).		
Unclear	"... [evolves] with spatial-temporal dynamics and ... [is] constantly changing under the influence of social, economic and environmental conditions" (p. 312).	-	[28], as cited in [161]
	"... [is] capable, over time, of embracing change and modulating the new with the existing, without a loss of overall coherence, diversity and, ultimately, resilience" (p. 19).	Diversity	[147]
	"... reduce[s] an area's specific risks, but also ... addresses our ever-changing environment and complex urban systems in a continuous bid for sustainable development" (p. 88).	-	[99]
	"The capacity of ... urban form to provide a fertile environment for economic prosperity and social cohesion ... " (p. 1056).	-	[123]
	"... [is capable] of responding to small-scale, largely self-organized dynamics of socio-cultural nature ... [such as] gentrification by 'collective action'" (p. 1061).	Responsiveness, self-organization	
	"... enable[s] local agents to respond to adverse events (disasters, disorder) or promising opportunities (new technologies) at any time in the future" (p. 353).	Responsiveness	[129]
	Responds and allows for change (or disturbance) by improving spatial connectedness and accessibility "... so that information, people, and biotic components ... can access each other and construct new constellations ..." (p. 7).	Interconnectedness, responsiveness	Authors' formulation based on [26]
	"... support[s] and develop[s] differences in human activity ..." (pp. 7–8) by creating spatial diversity (i.e., multiple, distinct spaces); allows for self-organization, i.e., the ability of the urban form elements to spatially re-organize and change structure when facing change, e.g., the presence of "shops [that] typically respond to new market demands by reconfiguring in new geographic clusters" (p. 8); and carries knowledge (or learning), for instance, by creating not only highly integrated spaces but also segregated ones that "... can work as pockets of memory for survival in crises and from which the system can be retrieved if the right connections are present" (p. 9).	Diversity, learning, self-organization	

Table 5. A selection of definitions of urban form resilience (or resilient urban form) identified in the reviewed publications focusing on specific stresses/shocks and/or urban form elements.

Focus	Definition	Source
Coastal cities' resilience	"... enhance[s] the coastal cities' resilience to tsunamis [by providing a system of open spaces that act] as an emergency evacuation directing point, as a primary place for emergency rescue, as an agent for temporary sheltering, as a facilitator for tsunami disaster mitigation and as a mediator to provide tsunami awareness" (p. 471).	[126]
Flood-impact resilience	"... [keeps] residential buildings out of the water thanks to a combination of technical solutions, and ... [encourages] risk awareness by resorting to the visible presence of water" (p. 19).	[75]
	"... progressively absorb[s] the flood impact to uphold new critical stability ... [and] maintains a minimum required level of functionality, a safe-to-fail strategy with a bounce-forth perspective" (p. 182).	[145]
	"... [enables] people to access safety destination and for the surface runoff to gently flow towards natural downstream without disturbing the urban context with inundation" (p. 189).	
	"... compact form[ ] of development [that is] ... better able to [reduce flood-related losses by] ... focus[ing] development intensity on the most suitable land available ... deter[ing] the release and subsequent development of flood-prone land elsewhere ... [and] have[ing] in place a flood mitigation infrastructure that can appropriately handle large amounts of runoff" (p. 791).	[77]
Economic resilience	"... the ability [of retail buildings/shops or urban shopping centers] to adapt to shocks while fostering a viable retail economy and strong public urban life simultaneously ..." (p. 553).	[105]
	"... allows households to adapt their behavior and possibly reduce travel in response to the changing economic climate" (p. 10).	[109]
Seismic resilience	"... [a polycentric, compact urban development pattern that] cause[s] less total seismic damage by shifting floor areas from the city center to ... subcenters away from most historical earthquakes" (p. 98).	[80]
	"... the capacity of [the] built environment to maintain acceptable structural safety levels during and after unforeseeable events, such as earthquakes, as well as to recover their original functionality" (p. 291).	[163]
Heat-stress resilience	"... [provides] outdoor spaces with more tree canopy, grass cover, and shadow coverage [that] tend to facilitate more frequent extended outdoor activities during summer ..." (p. 2).	[93]
	"... [possesses] passive preventive design features that do not require energy. [This includes, for instance,] ... reflective roofing, ceiling insulation, reflective foil in the roof cavity ... ceramic floor covering ... heavyweight walls ... slab-on-ground structures in warm climates ... garden vegetation, shading and appropriate orientation ..." (p. 280).	[130]
	"... the capability of the built environment to support outdoor activities during heat stress conditions" (p. 944).	[90]
	"... [promotes] climate responsive and socially interactive spaces" (p. 122).	[164]
Disease-outbreak/Health resilience	Minimizes the risk of virus spread at three different scales: (1) the building (e.g., by designing semi-open spaces in housing design like balconies for planting and pleasure, designing sanitation facilities shared by multiple households); (2) the neighborhood (e.g., by providing semi-public and semi-private or shared open spaces in residential buildings for planting, playing and working out in pandemic situations); (3) and the city (e.g., by creating less dense urban centers to decelerate the spread of diseases and avoiding locating cities at short distances).	Authors' formulation based on [104]

Table 5. *Cont.*

Focus	Definition	Source
	"... [promotes an increased] capacity for health resilience in the face of severe poverty" (p. 1104).	[115]
Warfare resilience	"... [supports] civilian survival practices during urban warfare" (p. 698).	[120]
Immigration-/migration-wave resilience	"... [is] capable of ingesting immigrations, adapting to the on-going changes and successfully responding to the needs of immigrants" (p. 768).	[111]
Ill-being resilience	"... [affords] a diversity of [positive human] experiences and a level of connectivity between them that limits adverse outcomes" (p. 187).	[118]
Individual resilience	"... provides psychological and physiological benefits to people [and allows them to learn coping and adaptation behaviors] by adding motivations to interact with the environment ..." (p. 3).	[165]
Resilience through streets and/or open/green spaces	"... [includes] a dormant network of streets, squares and parks, among other open areas, which in times of crisis can be prepared to adapt to uncertainty ... and provide temporal refuge, information, goods and medical care, among other survival needs" (p. 65).	[88]
	"... the capacity of an urban grid to maintain the operation of urban functional assets by redistributing movement after a physical perturbation" (p. 2).	[89]
Resilience through the type of development	"... dense and diverse urban [development] pattern[ ] ... [that provides] a redundancy of functions ... networkability and response diversity to disturbances ..." (p. 96).	[166]

4. Discussion

In urban research and policy, the concept of resilience has recently become a buzzword very favored to address the complexity and future uncertainty in cities. However, as discussed in this paper, resilience is a polysemic concept and can be interpreted in a multitude of ways, which works against its operationalization. Operationalizing resilience requires examining its underlying politics by specifying what will be made resilient to what, for whom, when and where, among many other relevant questions in the resilience literature. Specifically in urban morphology, there has been little effort to examine these underlying politics of resilience. Therefore, in this paper, we have conducted a systematic literature review (n = 106 peer-reviewed publications) to improve clarity and intelligibility in the field and better understand how resilience can be operationalized and integrated into the study of urban form.

4.1. The Nature of the Relationship between Urban Form and Urban Resilience

Our systematic literature review confirms and adds to the existing evidence that urban form has various implications for the resilience of cities, and hence it can direct them towards either sustainable or unsustainable trajectories. More specifically, the review suggests that the relationship between urban form and urban resilience is complex and multifaceted. An important part of this complexity comes from the fact that urban form is a complex system with many constituent elements that exist at different scales, overlap and influence one another [54,61]. Furthermore, each of these elements has its own adaptive cycle and changes at different speeds, with changes being slower and more difficult at larger scales [167]. As a result, each element exhibits resilience in a different way and requires different resources for operationalizing it. To acknowledge this complexity, we have followed a hierarchical approach [27,34,72,73] that categorizes urban form elements based on different scales [28]. These are the macro-, meso- and micro-scales, and where most of the reviewed publications have addressed meso-to-micro-scale elements of urban form, including buildings, open/green spaces, neighborhoods/sanctuary areas, land uses, blocks, plots, the underground space and the so-called urban project. What adds to this complexity is that each of the aforementioned meso- and micro-scale urban form elements,

as well as macro-scale ones, was found to enhance urban resilience, or the resilience of the urban population (both general and specified), to a great many disturbances. These disturbances can be classified as general unanticipated disruptions or specific existing threats but also as rapid-onset shocks (short-term disruptions such as earthquakes) or slow-onset stresses (long-term disruptions such as desertification and deforestation). Furthermore, in responding to these disturbances, urban form elements were found to exhibit different resilience performances, namely persistence, adaptability and transformability, depending on the kind of disturbance and its temporal scale of effect (e.g., persistence for short-term disruptions and adaptability or transformability for long-term ones). In relation to these resilience performances, it was found that urban form elements can be either persistent, adaptable or transformable/changeable in themselves (i.e., resilience of urban form) or can enhance people's persistence or provide them with opportunities to adapt and maintain basic functions during a disturbance (i.e., resilience through urban form), as described in Table 1.

Another part of this complexity of the relationship between urban form and urban resilience stems from the diversity of agents (direct and indirect) and agencies that were found in the literature to determine urban form resilience such as urban planners, urban designers, policy- and decisionmakers, politicians and architects. Each of these actors has their own goals and priorities but also different degrees of power to make the decisions about how resilience is applied, whose resilience is prioritized and where.

The review has also highlighted that in enhancing urban form resilience, there may be some potential negative consequences and trade-offs, particularly when not thinking through the different Wh-questions (i.e., who, what, when, how, etc.) related to operationalizing resilience. For instance, resilience approaches that oversimplify the issue of spatial scale may enhance resilience at one scale but can have negative impacts on resilience at other scales. Take, for example, the case of the compact urban development patterns (smart growth) that can reduce the overall flood losses at the city scale due to the concertation of the urban development in the most suitable land available but significantly increase surface runoff at the neighborhood scale due to the relatively high fraction of impervious surface cover. In fact, there has been a debate for a long time surrounding the sustainability of high-density/compact developments in urban areas, extending beyond just the issue of flooding [168]. For instance, on one hand, high-density urban developments can promote sustainability by reducing the need for urban sprawl and safeguarding natural and agricultural land outside cities. They can also encourage walkability and physical activity [169], increase the use of public transport [170,171] and provide better accessibility to public services [172,173]. On the other hand, many agree that compact urban developments can exacerbate the UHI effect due to increased building density [174,175] and threaten the provision of green and other recreational spaces which can affect the resilience of communities to a certain extent [31,176].

The review has also suggested that targeted resilience approaches towards some specific populations may have unintended negative consequences for other groups, as in the case of gentrification, where an urban form that accommodates minor but continuous adjustments over time and facilitates transformation may be undesirable for the original inhabitants who often face forced displacement.

In fact, the notion that achieving urban resilience may come at a cost can be supported by previous literature and several real-world cases [70,177–179]. For instance, previous studies have shown that resilience-building initiatives (e.g., to withstand the effects of climate change, such as increased flooding and heat threats) can lead to the temporary or permanent displacement of the population, particularly low-income or marginalized ones [180,181]. This is because land and properties may be acquired and, in some cases, existing housing may be demolished for development/re-development. These resilience efforts can also lead to unintended negative ecological and environmental impacts such as affecting species biodiversity in urban areas [182] and the suspension of sediments in urban water bodies [183]. In some cases, these efforts may also result in overlooking

cultural heritage, particularly during post-disaster planning [184]. Additionally, certain urban resilience investments, such as urban greening projects, have been demonstrated to increase land and property value which may lead to gentrification outcomes [185,186]. Other studies also highlighted that specific urban resilience investments can exacerbate social and economic inequalities, as resources and opportunities may be directed toward certain neighborhoods or groups of people [178,187]. This is the case of several state-provided climate adaptation/mitigation (or disaster risk reduction) projects that overlook the needs of low-income and minority populations [188,189] or exclude those living in underrepresented communities such as slums and informal settlements [190,191].

Furthermore, other examples from the resilience literature have pointed out that too much focus on the system's resilience to specific disturbances can increase its vulnerability to other ones [149] or lessen the effectiveness of its general resilience, as this reduces the system's diversity and flexibility among many other general resilience attributes [192,193]. Likewise, achieving long-term resilience targets comes at the cost of short-term ones [192]. These aforementioned potential negative consequences and trade-offs illustrate that "planning for resilience is inherently a struggle" ([194], as cited in [16], p. 9) and confirm earlier arguments in the literature regarding the importance of thinking through questions related to who, what, when, where and why, if resilience is to be effectively operationalized.

4.2. Implications for Urban Planning and Design Practice and the Future of Urban Resilience

In addition to providing an improved understanding of the nature of the relationship between urban form and urban resilience, this review offers several implications for urban planning and design practices. For example, based on the findings of this review, different urban planning and design considerations could be formulated. Table 6 lists a few examples of these considerations. However, it should be noted that these are only general recommendations, showing how resilience thinking can be incorporated into urban planning and design practice, and more specific guidelines would be needed on a case-by-case basis depending on which priorities are being considered and at what cost.

Table 6. Examples of general urban planning and design recommendations to enhance the resilience of different urban form elements.

Urban Form Element	Recommendation
Development type	Encouraging polycentric compact urban developments in flood- and earthquake-prone areas and less dense, linear ones in areas that are highly vulnerable to disease outbreaks and/or terrorist attacks.
Neighborhood/Sanctuary area	Incorporating semi-private/semi-public spaces that encourage social interaction and the development of social ties and solidarities in neighborhood design to enhance the resilience of local communities in times of crisis (e.g., during disease outbreaks and extreme heatwave events).
Open/Green space	Establishing a network of redundant, flexible and interconnected open spaces near highly connected streets to serve as points for evacuation, temporary sheltering and distribution of essential goods during crises.
Street	Designing street networks that increase path redundancy (e.g., grid-like networks) to offer alternative routes and maintain the functioning of the system in disaster-prone areas (e.g., to earthquakes, floods and fires) in aftermath conditions. More detailed planning/design recommendations regarding streets and street networks can be found, for example, in [29].
Plot	Creating fine-grained plots with a variety of sizes to accommodate a wide range of activities and facilitate adaptation to future changes such as economic fluctuations (e.g., boom–bust cycles).
Building	Developing buildings with flexible floor plans and modular construction techniques that can be easily adapted (e.g., expanded, reconfigured) to changing needs over time, such as ingesting immigration/migration waves, overcoming economic recessions and financial crises and adapting to deteriorating socio-economic conditions (e.g., increased urban poverty).

In the future, the incorporation of resilience thinking into urban planning and design research and practice is expected to expand as the concept continues to evolve driven

by new challenges faced by cities. These include, for instance, the increasing effects of climate change (e.g., more frequent and severe heatwaves), which will affect more cities globally, and the growing social and economic challenges (e.g., increased social inequalities and urban poverty). These challenges will drive cities to develop and invest in new and innovative urban resilience strategies and tools. Furthermore, the continuous advancement in technology, such as artificial intelligence (AI) and the Internet of Things (IoT), may play a role in shaping the future of urban resilience planning and design. These technologies can, for example, provide new promising tools and novel data for cities to assess risks and make better-informed decisions, thus improving their resilience.

4.3. Limitations of the Review

Although the systematic literature review conducted in this paper aimed to provide a comprehensive understanding of the relationship between urban form and urban resilience, it has a number of limitations that may have caused some biases, and therefore the results should be interpreted with caution.

Firstly, this systematic review has relied only on two databases for the identification of potentially eligible studies, namely Scopus and WoS. Although these are the widest multidisciplinary databases available at the moment, and which together provide relevant scientific content from 1956 to the present, some relevant studies may not have been included. Furthermore, these databases focus mainly on publications written in English, which gives the results an Anglo-American bias [195], and they do not generally include books. For these reasons, other supplementary databases could have been used in the review, such as PubMed, Dimensions and Google Scholar.

In addition to these database limitations, the search script used in this review to retrieve relevant publications (Table S1, Supplementary Materials) may have caused an unintentional exclusion of important studies. For instance, the search term "resilien*" (i.e., resilience, resiliency, resilient) does not ensure the inclusion of studies that implicitly speak of resilience; use parallels to the concept of resilience; or focus only on specific resilience performances (i.e., persistence, adaptability and transformability) or attributes (e.g., diversity, redundancy). Furthermore, searching for potentially eligible publications only using titles, abstracts and keywords, and not the full text, is another major limitation that may have resulted in the exclusion of relevant studies. This is because titles, abstracts and keywords include only limited information [196]. These limitations in the search script and in the search method have indeed eliminated some important studies that discuss, for instance, the importance of plots (e.g., [40,197,198]) and blocks (e.g., [199]) for enhancing urban resilience to different specified and general disturbances.

Finally, considering that systematic reviews are time- and effort-consuming, several other publications may have been published since the end date set for our search. Obviously, these were not included in the review. However, the body of sources reviewed (n = 106) is considered extensive enough to reach useful findings and conclusions for those parties involved in urban planning and design decision making and policy. In the future, there is more work to be carried out to better investigate specific aspects of the complex relationship between urban form and urban resilience, but this review can be considered a starting point that highlights a variety of key aspects that need to be taken into account when approaching this topic.

5. Conclusions

In this paper, to clarify the ambiguity of the core meaning of resilience in urban morphology and examine its underlying politics in light of growing interest in and the publication of several studies on the topic, we have conducted a comprehensive systematic literature review based on 106 peer-reviewed publications (288 before screening and assessment) that were retrieved from two scientific databases (i.e., Scopus and Web of Science). The reading and analysis of the full publications, which was guided by a set of relevant questions (e.g., resilience of/through what? To what? For whom? How? When? Where?),

have provided an improved understanding of the nature of the relationship between urban form and urban resilience from many different aspects. Moreover, it offered a detailed overview of how the combination of urban form and urban resilience has been used across disciplines and fields of study, where 41 different definitions of urban form resilience, or resilient urban forms, were identified. Most importantly, the review has shown that the relationship between urban form and urban resilience is complex and multifaceted with a great many urban form elements that can enhance the resilience of the urban population (both general and specified) to a great many disturbances (general/specified and slow-/rapid-onset). Furthermore, in responding to these disturbances, urban form elements were found to exhibit different resilience performances (i.e., persistence, adaptability and transformability), where they can be resilient in themselves (i.e., resilience of urban form) or can increase people's persistence/adaptation capacity during a disturbance (i.e., resilience through urban form). Also, several actors, with different points of view, priorities and powers, were found to be involved in the planning/design process of urban form resilience. Lastly, the review highlighted that there are some pitfalls in applying resilience thinking in urban morphology and pointed out that achieving urban form resilience may have potential negative consequences or trade-offs. Based on this complexity, we decided not to give one definition or provide a single understanding of the meaning of urban form resilience (or resilient urban forms), which may indeed undermine this desired complexity. Rather, we offer the readers a rich overview of the many perspectives on the topic, along with examples of potential implications for urban planning/design practice, so that they may decide which perspective may be most appropriate for their specific research question(s) and aim(s) but also to stimulate new ideas of how urban form can contribute to urban resilience.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/urbansci7030093/s1, Table S1. Search blocks used in Scopus and WoS databases to retrieve relevant publications eligible for the systematic literature review. Table S2. A matrix of the relationship between the urban form elements (rows) and the different disturbances (columns) that they were found to provide resilience to.

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