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The resilient city: What urban form characteristics to adapt to flood risks? (Case of the city of Skikda-Algeria)

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Abstract:
Disaster risk reduction has become a global consensus and an integral part of sustainable development. The built environment can mitigate or exacerbate the spread of flood risks and help to achieve resilience. This paper questions the characteristics of resilient urban forms to adapt to flood risks in urban areas. This concern was analysed using a methodology based on urban morphological indicators, applied to the city of Skikda in north-eastern Algeria.
The results identify five key factors of resilient urban form which are: connectivity, diversity, redundancy, modularity and finally efficiency; their potential is to identify gaps and uncertainties to establish possible links between geometric parameters characterizing urban forms and key indicators of urban flood severity.
Keywords: urban form; flood risk; resilient city; adapting; indicators; Skikda.

Highlights

- Urban resilience enhances the adaptability of the built environment to flood risks.
- Formulate an original theoretical framework that emphasizes the role of urban form in building resilience at the neighbourhood scale.
- Operationalise the proposed theoretical framework through a series of practical assessment tools aimed at measuring the resilience capacity of urban form in real case studies.
- Formalise new Factors related to the assessment of urban resilience

1. Introduction

Cities are complex systems of socio-cultural and natural features (Battemarco et al., 2022; UNDRR, 2009; Amen, 2021; Aziz Amen, 2022; Amen et al., 2023; Amen & Nia, 2020; Aziz Amen, 2017; Aziz Amen & Nia, 2018; Amen & Kuzovic, 2018; Amen & Nia, 2021). Since modern times, cities have developed rapidly, and urban forms are facing serious problems due to the lack of adaptability to crises such as urban waterlogging. Flooding can cause spaces that would not normally be flooded to be flooded (Lumbroso & Vinet, 2011; Sudmeier-Rieux et al., 2019). The floods are among the most destructive, killing tens of thousands of people in developing countries (UN New York, 2015). In Algeria, an urban fabric primarily for specific uses (e.g. residential) can lead to high building densities, leaving limited open and green spaces that have lost their ability to infiltrate stormwater and are now at risk of flooding (Abdelkebir et al., 2021). In other words, building urban resilience is beneficial when planning for the future of urban areas to reduce the impact of flooding (Davoudi et al., 2012; Juan-García et al., 2017). The role of urban form in increasing urban resilience has been largely unnoticed and is now attracting considerable academic attention. The development of an evaluation framework to assess the extent of resilience of urban areas can be an effective way to integrate resilience-related issues into the urban planning process (Sharifi & Yamagata, 2017).
The objective of this work is to design a framework to select mainly the general criteria for assessing the resilience of urban form to reduce flood risk (Lu et al., 2021), namely diversity, flexibility, modularity and redundancy, efficiency. To fill this gap, the present research aims at: a) identifying the relationships between urban form and resilience to urban flooding; b) developing new principles to test the resilience assessment of urban forms on indicators taking into account the specific conditions of the medj-edib flood-prone district in Skikda.

2. Contemporary Discourse on Urban Resilience

Urban resilience emerges in response to threats to urban survival and sustainable development (Kong et al., 2022). Urban resilience stems from the concept of ecological resilience, first introduced in Holling's 1973 book Resilience and Stability of Ecosystems, as "the ability of a system to absorb disturbances and reorganize itself as they change, while maintaining Basically the same functionality.", structure, identity and feedback (Rega & Bonifazi, 2020; Bautista-Puig et al, 2022, 2022; Juan-García et al., 2017; Lu et al., 2021; Meerow et al., 2016; Newell & Cousins, 2015; Tong, 2021). The complex concept of resilience has expanded to include multiple disciplines, including engineering, ecology, sociology, economics, urban planning, and architecture. Issues related to urban resilience and related fields have become a hot topic of discussion (Beilin & Wilkinson, 2015). The IPCC has defined resilience as "the ability of a system and its components to anticipate, absorb, adapt to, or recover from the effects of a hazard event in a timely and effective manner, including through the preservation, restoration, or enhancement of its essential basic structures and functions". This theme has been reinforced by the New Urban Agenda (2017), which calls on cities to "build resilience and responsiveness to natural and man-made hazards, and promote mitigation and adaptation to climate change" (United Nations, 2017). Resilient cities act only on major shocks by reducing chronic stresses, with rapid and effective recovery, in a socially acceptable way. It is: adapting (pre-crisis), surviving (during the crisis) and bouncing back to normal (post-crisis) to make cities robust (Fig.1).

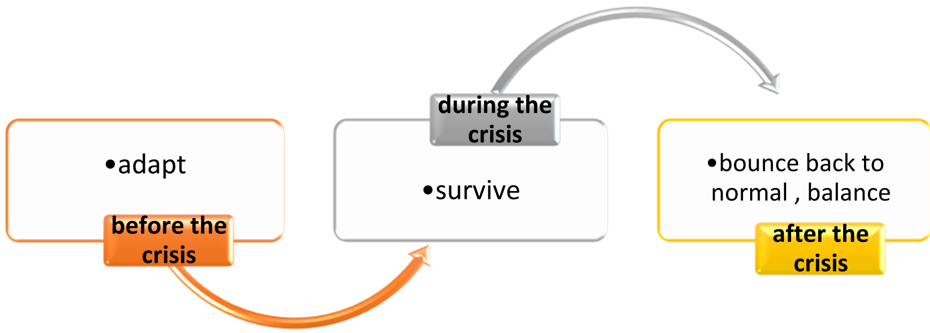

Fig1. Conceptual diagram of the resilient city process (By author).

The growing number of studies on urban flood resilience is closely linked to climate change. Extreme weather conditions caused by climate change will have an irreversible impact on the built-up areas of cities, and will even cause major damage to the outskirts of cities after floods. Urban resilience is a solution to prepare the urban system for any new disturbance and to respond to and adapt to the ongoing shock of floods. The study of urban flood resilience is deepening, which also reflects the continuous improvement of our capacity to respond to urban floods (Gao, M.; et al 2022). Regarding the characteristics and dimensions of resilience in urban flooding, most researchers agree on the 4Rs theory ,namely that it has four characteristics - robustness, rapidity, redundancy and ingenuity, and four dimensions - technological, organisational, social and economic (Sun et al 2022). The imbalance between the supply of urban form and the risk of flooding results from urban growth. Urban form resilience is one of the subsets of the urban resilience discourse, and although research and articles have been written on urban form resilience and how to assess it over the past decade, this issue is still at the conceptual and exploratory stage. These studies have linked urban form and the concept of resilience based on the axiom that the physical structures of cities influence non-physical dynamics such as human mobility and information flow (Biljecki et al., 2021; Haigh et al., 2020; León et al., 2018). Improving the resilience of cities to external disturbances becomes a more important method to mitigate the impact of urban flooding (Wu et al., 2022).

3. Material and methods

3.1. Case study and data issues

The district of Merdj-Edib in the low-lying area of the city of Skikda, north-eastern Algeria 29°36’37.1”N, 52°31’52.1”E (Fig. 3), is used as a cross-sectional case study, one of the largest cities in the city, it was necessary to divert road traffic to other routes to allow citizens to return to the city centre; with a total area of about 240 km ^{2}, and a population of about 1.55 inhabitants. The district is prone to flooding due to its proximity to rivers and the flat topography, causing significant human and economic losses. Flooding is also a major hazard as the daily rainfall reaches about 400mm - 700mm. The important stagnation that this zone undergoes is essentially due to the clogging of the rainwater channel coming from the boulevard Houari BOUMEDIENE, which receives the wastewater from the neighbouring buildings. Merdj-Edib presents different urban patterns, which makes it a suitable case for spatial analysis in order to be able to represent a wider variety of morphological components (i.e. different types of streets, street edges, parcels, and blocks).

The main geographic data included location, topology and geometry data of parcels, street edges, blocks, represented as lines and polygons to clearly distinguish morphological components such as streets, parcels, blocks, building footprints, stored as geolocated vector features, mainly from OS MasterMap.

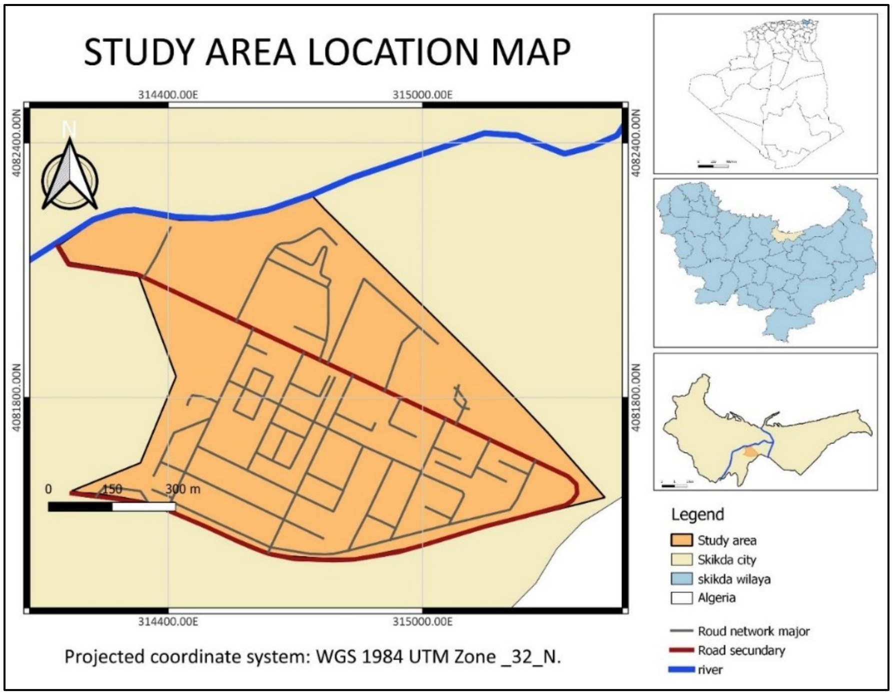

Fig 2. Location of the study area.

3.2. Methodology

Recently, the use of spatial data to assess urban resilience has become more popular. As we all know, the Geographic Information System (GIS) allows the recording, analysis and synthesis of data at different spatial and temporal resolutions, thanks to its recognized efficiency (Alberico et al., 2020; Malczewski, 2006). Based on this, several researchers have assessed spatial resilience using an indicator-based system, a multi-criteria assessment method and a GIS-based spatial visualisation (Meerow & Newell, 2017).

This study attempts to fill the gap in the development of urban resilience indices using a case study approach, involving a brief literature review to assess the resilience of urban form in urban fabrics, particularly those facing the challenge of flood risk (Bourlier et al., 2021; Rolf et al., 2022). The data required for the analysis was obtained from two main sources, namely the PDAU of Skikda and Open Street Map. While the spatial analysis procedures performed are carried out using different toolkits available in the QGIS software. For this purpose, the options considered are:

- Characterise the target urban area which simultaneously presents different morphological patterns, sensitive to flooding (flat agglomeration and crossed by a watercourse) and considering the dense concentration of buildings.
- discuss the selected indicators and their potential links to resilience: 5 indicators have been developed of the resilience of the urban form against flood threats
- Mapping and analysis of indicators related to diversity, redundancy, connectivity, modularity and efficiency using QGIS.

4. Results and Discussion

To turn resilient cities into a measurable concept, researchers are attempting to develop resilience metrics. Building on previous research (Ahern, 2011; Alawneh & Rashid, 2022; Alessandra Feliciotti, 2018; Zhang et al., 2020), the findings of this study can serve as a basis for defining a specific set of indicators that represent potential assessment tools for measuring resilience to urban development and insecurity.

Table 1 and Figure 3 shows the identified attributes belonging to a resilient urban form that is valid everywhere and for everyone (diversity, redundancy, connectivity, modularity and efficiency) (Zhang et al, 2020). This demonstrates the effective resilience of urban agglomerations (Burton, 2015), given that flooding is often associated with significant economic and human losses (Kunreuther & Lyster, 2016), providing an understanding of how complex systems, especially urban ones, operate over time and at different levels (Butler et al., 2017). During the research process, it is important to clarify how each indicator contributes to or hinders urban resilience. As a result, the presence or absence of a certain attribute can increase or decrease the likelihood of flood risk, or influence the effectiveness of a system to cope with stresses or shocks. Depending on the different research needs, the importance of each indicator is different.

Table 1: Representative indices of urban resilience to shocks in the urban form.

Attributes	Definition	measurement tools
diversity	The core concepts of elasticity theory describe a system that is heterogeneous, general, multifunctional, as well as variable, delayed, and uncertain, without structural changes, and that can operate in a variety of situations. Furthermore, diversity is critical for adaptability. Because internal differences between components allow a system to change its configuration more easily over time in response to changing external conditions (Albers & Deppisch, 2013; Dhar & Khirfan, 2017; Godschalk, 2003).	Distribution, typology and functions of blocks and plots, diversity of blocks in shape and size.
Connectivity	The main factors in the design of cities and their communities describe the ability to communicate easily within and between systems (Feliciotti et al., 2016) and show the strength of interactions between urban elements (Salat et al., 2010; Samuelsson et al., 2019). Connectivity in resilience has two aspects: higher connectivity helps absorption and recovery, lower connectivity reduces propagation of interruptions and preserves memory by limiting fragmentation (Biggs et al., 2015; Marcus & Colding, 2014; Mehaffy et al., 2010).	The layout of the streets and the elements, properties and functions of the network.
Redondancy	Redundancy is a structural property of urban form independent of any particular future scenario. Redundancy describes a system in which different components provide multiple overlapping ways to perform the same function (Ahern, 2011) and are connected to each other through multiple pathways (Salat et al., 2010). Careful subdivision of urban blocks and neighborhoods, with some degree of mixing in different areas, will lead to a more redundant urban form (Feliciotti et al., 2016).	The distribution and typology of spaces that allow an opportunity to reorganise.
Modularity	Modularity describes a system where functionality is distributed locally and distributed across decentralized subsystems (Ahern, 2011). Internally, modules are connected by strong, narrow internal links, while externally, they are linked together by relatively weak long-distance links (Salingaros, 2000). Modularity is critical to resilience. With relative autonomy, each module or subsystem can avoid over-connectivity: it can fail without seriously affecting other modules and testing new modules.	Measurement of different layers in urban cores such as different dense activities, and natural areas (Mehaffy et al., 2010).
Efficiency	A general definition of efficiency is the ability of a system to achieve desired results while avoiding wasting resources and time. In urban form, this means maintaining the functions of static urban form in relation to dynamic processes (Godschalk, 2003; Kim and Lim, 2016). The concept of elastic efficiency, while often cited, is controversial. Efficiency reduces the urban resilience of simple urban forms. However, more complex urban forms are more efficient structures, with different elements at different scales. Efficient urban forms are often a mixture of a large number of small, flexible elements mixed with a few larger elements that support each other (Dovey & Wood, 2015). The geometric compatibility or incomparability of fragmentation and consolidation depends on: the size of the footprint relative to the block the shape of the buildings that define the shape of the block.	Block geometry and typology.

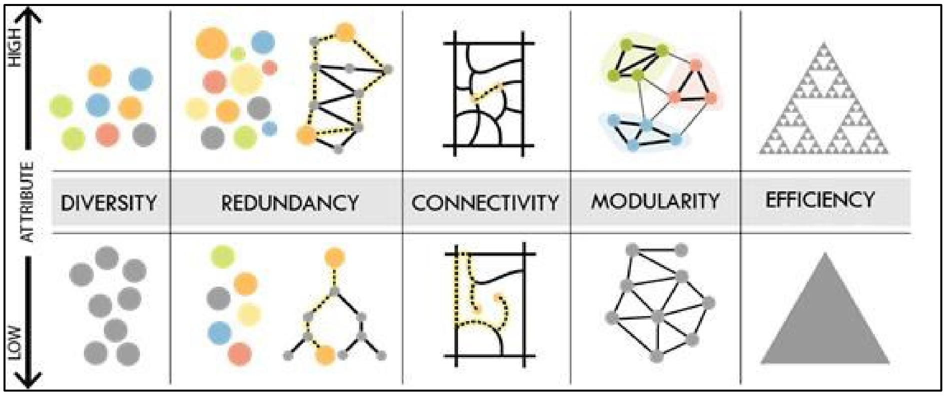

Fig 3. Illustration of the five resilience attributes (Alessandra Feliciotti, 2018).

The most important step in improving urban resilience is to assess the current level of resilience (Kong et al., 2022). The configuration and geometric features of relevant urban forms were taken into account when evaluating resilience indicators in the study area (Chen, 2016; Huang et al., 2021; Wang et al., 2022). The study shows that very limited green space, relatively small open space and moderate centrality (nodes/links in the road network) and functional mix value (residential, commercial, institutional and transport) influence the reduction of resilience capacity. Large blocks, on the other hand, affect flood resilience because large paved blocks with limited green space increase stormwater runoff and thus flood risk (Fig .4).

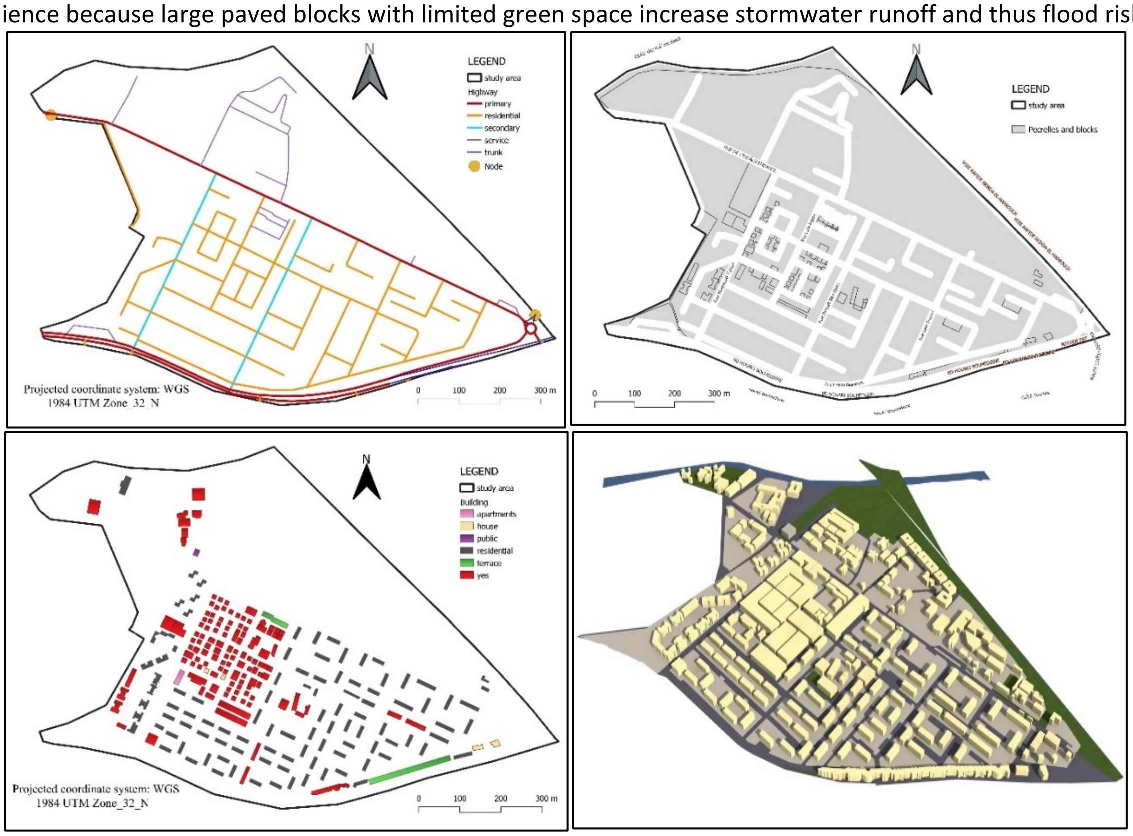

Fig 4. Configuration of the morphological parameters of the study area (by author).

Conclusion

Based on the five urban form indicators (diversity, redundancy, connectivity, modularity and efficiency) of Skikda's Merdj-Edib district, this paper examines their potential for designing resilience as a solution to flooding. The results of this research can be used to develop planning and design strategies to achieve flood resilient urban development. The process of assessing resilience using these indicators would help decision makers to get a clear and complete picture of the resilience of the development proposal and help them to make better informed decisions.

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Conflict of Interests
The authors declare no conflict of interest.

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