

Galimberti B (2022)

Adger DWIN (2006)

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Adelhart Toorop R de... Lopez S (2021)

Rauws W (2017)

# Towards antifragile cities: A systematic literature review

Sorensen AD (2009)

Taleb N (2012)

timashe... (2020a)

Blecic I Cecchini A (2020)

Acierno A Lanzi G (2018)

Dezio C Dell'Ovo M Oppio A (2021)

Gkoumas K Petrini F Bontempi F (2023)

**Hacia ciudades antifrágiles:**  
una revisión sistemática de la  
literatura

**Vers des villes antifragiles :**  
une revue systématique de la  
littérature

**Rumo a cidades antifrágiles:**  
uma revisão sistemática da  
literatura

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## Abstract

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Antifragility is a concept that enables a potential benefit from crises and catastrophes to emerge. However, in this respect there is a lack of information in the architectural, urban, and territorial fields. The aim of this systematic literature review is to respond to the following questions: How is urban antifragility defined in recent research? What characteristics enable architecture, city, and territory to be antifragile? And how has it been evaluated? Following the PRISMA guidelines, papers published between 2011 and 2023 that contained the term 'antifragility' in their titles, in English or Spanish, were collected from 8 databases. A total of 425 publications were evaluated and 52 articles were selected for analysis. Twenty-six proposed indices and indicators were analyzed using 19 characteristics of urban antifragility. As a result, a definition of urban antifragility and five analytical dimensions are proposed, that is, dynamic configuration, synergic processes, strategic governance, epistemic management, and systemic development. It was concluded that the shift from theoretical discourse to the assessment and implementation of urban antifragility imply prioritizing flexibility and optionality, together with the incorporation of indicators related to information and knowledge.

**Keywords:** urban planning, resilience, disasters, urban renewal, risk management

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## Resumen

La antifragilidad es un concepto que posibilita convertir una crisis en beneficios, del cual existe muy poca información en los ámbitos arquitectónico, urbano y territorial. En consecuencia, esta revisión sistemática de la literatura busca responder lo siguiente: ¿Cómo se define la antifragilidad urbana en las recientes investigaciones? ¿Qué características permiten que la arquitectura, la ciudad y el territorio sean antifrágiles? ¿Cómo se ha evaluado? Se siguió la guía PRISMA y se seleccionaron artículos desde el año 2011 hasta 2023 que contienen en su título la palabra 'antifragilidad' en inglés y español, recopilados desde 8 bases de datos. Se evaluaron un total de 425 publicaciones y se seleccionaron 52 artículos para su análisis. Se analizaron 26 propuestas de índices e indicadores utilizando 19 características de antifragilidad urbana. Como resultado se propone una definición y cinco dimensiones de análisis para la aplicación de la antifragilidad urbana: configuración dinámica, procesos sinérgicos, gobernanza estratégica, gestión epistémica y desarrollo sistémico. Se encontró que la transición del discurso teórico a la evaluación e implementación de la antifragilidad urbana supuso priorizar la flexibilidad y la opcionalidad, así como integrar indicadores relacionados con la información y el conocimiento.

**Palabras clave:** planificación urbana, resiliencia, desastres, renovación urbana, gestión de riesgos

## Résumé

L'antifragilité est un concept qui permet de transformer une crise en avantages, mais dont on dispose de très peu d'informations dans les domaines de l'architecture, de l'urbanisme et de l'aménagement du territoire. Par conséquent, cette revue systématique de la littérature vise à répondre à la question suivante : comment l'antifragilité urbaine est-elle définie dans les recherches récentes ? Quelles sont les caractéristiques qui permettent à l'architecture, à la ville et au territoire d'être antifragiles ? Et comment cela a-t-il été évalué ? Nous avons suivi les directives PRISMA et sélectionné des articles de 2011 à 2023 contenant dans leur titre le mot antifragilité en anglais et en espagnol, recueillis dans 8 bases de données. Au total, 425 publications ont été évaluées et 52 articles ont été retenus pour l'analyse. Vingt-six indices et indicateurs proposés ont été analysés à l'aide de 19 caractéristiques de l'antifragilité urbaine. Une définition de l'antifragilité urbaine et cinq dimensions analytiques sont proposées. Il a été conclu que la transition entre le discours théorique et la mise en œuvre de l'antifragilité urbaine a donné la priorité à la flexibilité et à l'optionnalité, ainsi qu'aux indicateurs liés à l'information et à la connaissance.

## Resumo

A antifragilidade é um conceito que permite que surjam benefícios potenciais a partir de crises e catástrofes. No entanto, neste aspecto, há uma falta de informação nos campos da arquitetura, do urbanismo e do território. O objetivo desta revisão sistemática da literatura é responder às seguintes perguntas: Como a antifragilidade urbana é definida em pesquisas recentes? Quais características permitem que a arquitetura, a cidade e o território sejam antifrágiles? Como ela tem sido analisada? Seguimos as diretrizes PRISMA e selecionamos estudos de 2011 a 2023 que continham em seu título a palavra antifragilidade em inglês e espanhol, coletados em 8 bancos de dados. Um total de 425 publicações foi avaliado e 52 artigos foram selecionados para análise. Vinte e seis índices e indicadores propostos foram analisados usando 19 características de antifragilidade urbana. Como resultado, propõe-se uma definição de antifragilidade urbana e cinco dimensões analíticas, a saber: configuração dinâmica, processos sinérgicos, governança estratégica, gestão epistêmica e desenvolvimento sistêmico. Constatou-se que a transição do discurso teórico para a avaliação e implementação da antifragilidade urbana implicou priorizar a flexibilidade e a opcionalidade, assim como integrar indicadores relacionados à informação e ao conhecimento.

**Palavras-chave:** planejamento urbano, resiliência, desastres, renovação urbana, gerenciamento de riscos

**Towards antifragile cities:**  
A systematic literature review

**Mots-clés :** planification urbaine, résilience, désastre, rénovation urbaine, gestion des risques

## Introduction

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The Anthropocene has been characterized by intensified interaction between humans and natural systems (Shearer et al., 2021, p. 82; Equihua et al., 2020, p. 1) and by the accelerated transformation of their habitat, exposing human settlements to multiple forms of uncertainty, such as climate stress, urban complexity and socio-economic instability (Sartorio et al., 2021, p. 153; Gkoumas et al., 2022, p. 122).

Traditionally, these phenomena have been addressed through frameworks focused on prediction and risk management (Roggema, 2019, p. 113; Galimberti, 2019, p. 3134; Taleb, 2013, p. 178); nevertheless, many of the events that affect cities are characterized by unpredictability (Timashev, 2020, p. 2), and some of them are commonly described as 'black swans' (Gkoumas et al., 2022, p. 132).

Since the 1970s, the concept of resilience has been incorporated into scientific literature (Gkoumas et al., 2022, p. 21; Chiffi & Curci, 2024, p. 19) and, subsequently, into urban studies, promoting approaches focused on adaptation and recovery (Gkoumas et al., 2022, p. 119; Chiffi & Curci, 2024, p. 19). Nevertheless, several authors have pointed out that a return to previous conditions may not be possible or desirable (Sartorio et al., 2021, p. 142; Blečić & Cecchini, 2017, p. 2).

As such, antifragility emerges as an approach oriented towards generating benefits and positive transformations from crises and disruptions (Adelhart Toorop et al., 2023, p. 3), particularly relevant in a global context characterized by escalating climate risks, widening socio-economic inequalities, and recurrent urban crises.

However, the concept has been controversial (Babovic et al., 2018, p. 10; Blečić & Cecchini, 2019, p. 495). Various authors point out that its application in governance requires clarifying its ethical conditions, beginning with the question 'to be antifragile from what to what?' (Blečić & Cecchini, 2020, p. 16) since a system can become antifragile at the expense of the fragility of others.

In order to better understand this analytical framework, the following research questions are set forth to guide and structure the analysis in the subsequent sections:

1. How is urban antifragility defined in the context of recent research?
2. What are the dimensions involved in urban antifragility?
3. What are the characteristics that enable the city, territory, and architecture to be antifragile?
4. How has urban antifragility been assessed in previous research since the concept was introduced?

For the purposes of this article, urbanism is operationally understood as a multiscale political-ecosystem continuum for analyzing the urban phenomenon as a system of interdependent relationships, extending from the built habitat to territorial supports and governance capacities

*As such, antifragility emerges as an approach oriented towards generating benefits and positive transformations from crises and disruptions (Adelhart Toorop et al., 2023, p. 3), particularly relevant in a global context characterized by escalating climate risks, widening socio-economic inequalities, and recurrent urban crises.*

Databases	Syntax	Filters	Last query
Google Scholar	allintitle: ("anti fragility" OR "anti fragilidad" OR "anti frágil" OR "anti fragile" OR anti-fragility OR antifragile OR antifragilidad OR antifrágil OR anti-frágil OR anti-fragile OR anti-fragility OR anti-fragilidad)	Ninguno	Ene-24
EBSCO	AND antifragility Title OR "anti fragility" Title OR anti-fragility Title OR antifragile Title OR "anti fragile" Title OR anti-fragile Title OR antifragilidad Title OR "anti fragilidad" Title OR anti-fragilidad Title OR antifrágil Title OR "anti frágil" Title OR anti-frágil Title	Peer-review	Nov-23
Scopus	( TITLE ( antifragility ) OR TITLE ( anti-fragility ) OR TITLE ( "anti fragility" ) OR TITLE ( antifragilidad ) OR TITLE ( anti-fragilidad ) OR TITLE ( "anti fragilidad" ) OR TITLE ( antifragile ) OR TITLE ( anti-fragile ) OR TITLE ( "anti fragile" ) OR TITLE ( antifrágil ) OR TITLE ( anti-frágil ) OR TITLE ( "anti frágil" ) )	Ninguno	Nov -23
Ovid	A multi-field search was selected to enter each term. All available resources were selected.	Ninguno	Nov -23
MDPI	The advanced search option was used to enter each term. The page does not display the syntax.	Ninguno	Nov -23
Scielo*	(ti:(antifragilidad)) OR (ti:(anti-fragilidad)) OR (ti:(“anti fragilidad”)) OR (ti:(antifrágil)) OR (ti:(anti-frágil)) OR (ti:(“antifrágil”)) OR (ti:(antifragility)) OR (ti:(“anti fragility”)) OR (ti:(anti-fragility)) OR (ti:(antifragile)) OR (ti:(“anti fragile”)) OR (ti:(anti-fragile)) OR (ti:(antifragilidade)) OR (ti:(anti-fragilidade)) OR (ti:(“anti fragilidade”))	Ninguno	Nov -23
Repositorio UNAM	The manual search option was used to enter each term. The page does not display the syntax.	-	Nov -23
Redalyc	Antifragilidad OR anti-fragilidad OR antifrágil OR anti-frágil OR antifragility OR anti-fragility OR anti-fragile OR antifragile OR "anti fragilidad" OR "anti fragility"	-	Nov -23
Source: Authors.			

Table 1. Databases and corresponding search syntax

Source: Authors.

Note. \* It was also added in Portuguese.

(Munizaga Vigil, 2015, p. 20; Rueda Palenzuela, 2019, p. 724; Elias Bibri, 2020, p. 7; Galimberti, 2021, p. 3), thereby enabling the integration of architectural, urban, territorial, and ecological approaches.

Essentially, following a preliminary analysis of the literature, it was decided to conduct a systematic literature review (Azarian et al., 2023, p. 9) on the basis of the following reasons: (1) an absence of a systematic review on the subject was identified, (2) the literature on the matter is scarce, and (3) there is a gap in knowledge on the application of the concept in architectural, urban and territorial fields (Arvayo-Ballesteros et al., 2025, p. 239).

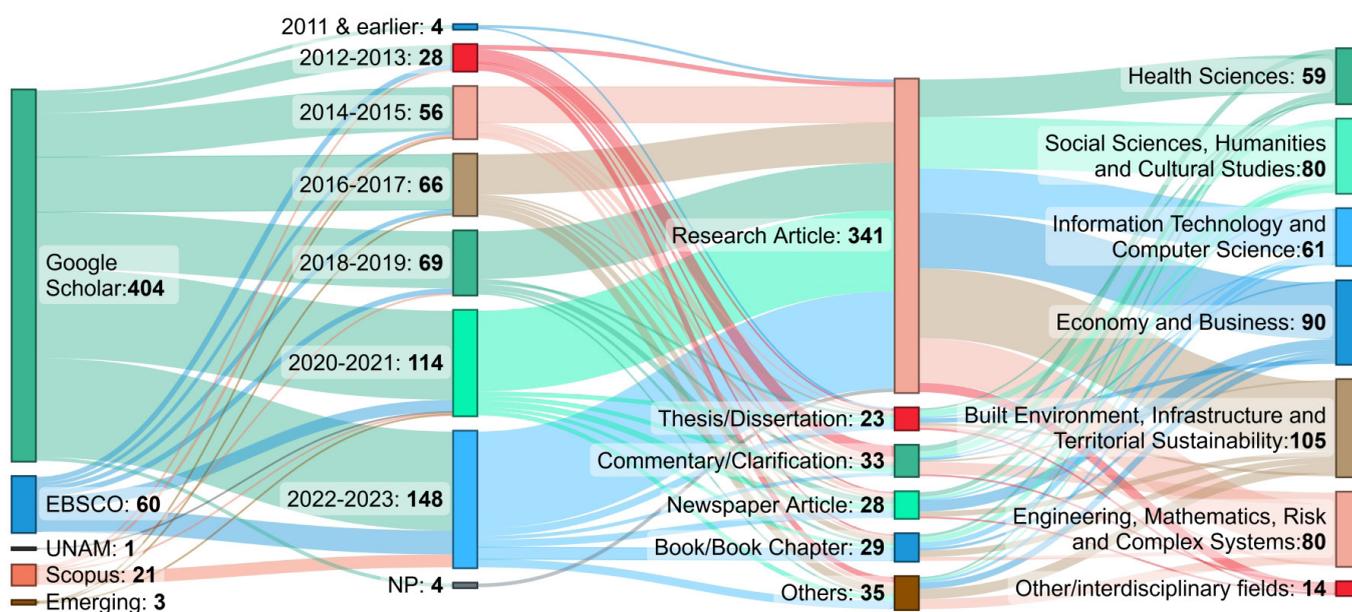
## Method

The systematic review aims “to provide an up-to-date summary of the state of research knowledge” (Higgins et al., 2019, p. 3). On this occasion, regarding the application of the concept of antifragility with respect to architecture, cities and territorial areas. In this regard, the Cochrane

Handbook and the PRISMA method (Preferred Reporting Items for Systematic reviews and Meta-Analyses), as well as other relevant literature on the matter, were considered (p. 8). Additionally, a specific procedure was created (Schmid et al., 2021, p. 4; Azarian et al., 2023, p. 14), comprising inclusion and exclusion criteria (Higgins et al., 2019, p. 5), as well as syntax (Schmid et al., 2021, p. 8), which are described in the following sections.

The criteria for inclusion and exclusion of papers were as follows: (1) the title must contain the term antifragility or one of its variants in English or Spanish; (2) the paper must cover an architectural, urban, or territorial issue; and finally (3) antifragility must be the principal concept analyzed. The search for information was conducted through various databases (Table 1) to ensure the maximum possible diversity of records and global representation (Schmid et al., 2021, p. 2).

The search syntax was adapted to each database (p. 8) to capture variations in the use of the term “antifragility” in titles, in English and Spanish. Hence, the total number of records eligible for evaluation (n = 422) was obtained,



**Figure 1.** Distribution of antifragility publications across databases, periods, types, and themes  
Source: Authors.

the title and abstract of each record was read (p. 3), and the information was classified as described in Figure 1, that is, source database, year, document type, and main topic. Finally, the records were labelled as 'compliant/non-compliant'.

In order to examine information from papers and publications related to the questions formulated, bibliographic records were compiled. Furthermore, the characteristics identified related to antifragility and its indicators proposed by the authors of the papers as a method of assessment were evaluated.

## Results

A total of 1,143 records were retrieved, of which 474 were removed due to duplication or inconsistencies and 183 because they were incomplete. A total of 486 records were included in the papers searched for access. Of these, 64 were unavailable and 373 publications were excluded for various reasons (Figure 2).

Figure 1 shows a steady annual increase in antifragility-related records, indicating growing academic interest, particularly in research articles, while in Figure 3 theses and dissertations provide deeper insights and even increase over time. Also, given the context of the cited documents, Figure 3 indicates that although the bulk of citations is anchored in foundational publications from 2012–2015, a smaller resurgence of high-impact articles appears in 2019–2020.

For this study, documents from 66 countries were reviewed. Figure 4 shows the origin of the documents, with the United States and Italy leading academic production on the subject, followed far behind by the United Kingdom, Australia, Mexico, and Iran, all within the top decile.

After screening the titles and abstracts of the papers, 52 were collected, of which 49 were available and three were provided voluntarily by the authors<sup>[2]</sup>. Grey literature was accepted to tackle the fragmentation of knowledge on the matter (Higgins et al., 2019, p. 79).

Figure 5 shows that Europe leads the field in urban antifragility, while other regions (including Latin America) remain behind or even non-existent, as in Africa. The growing body of European research on antifragile urbanism points toward a potential paradigm shift in policy frameworks. However, the limited production of studies originating in other regions may contribute to a Eurocentric trajectory in the field. Table 2 shows each of the main topics of the documents selected, including year, authors, and spatial scale.

Additionally, publications from Europe and other regions grouped between 2017 and 2021, while multi-country studies emerge in 2018 and concentrate in 2021–2023, focusing on Urban and Regional scales, indicating later integration without replacing region-specific research.

[2] These papers were requested from the authors via email or the Researchgate site. The number of papers requested was 11, of which only three were submitted.

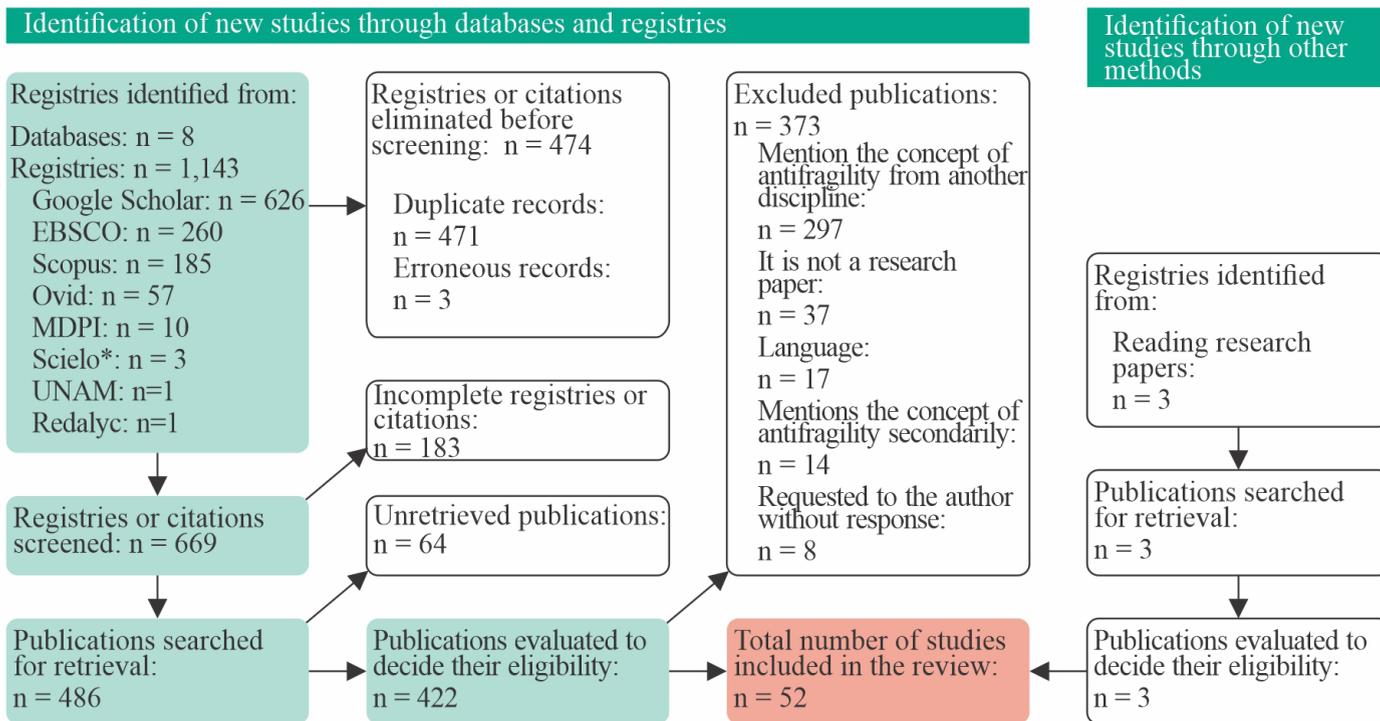


Figure 2. Flow diagram of the search and screening process  
Source: Authors.

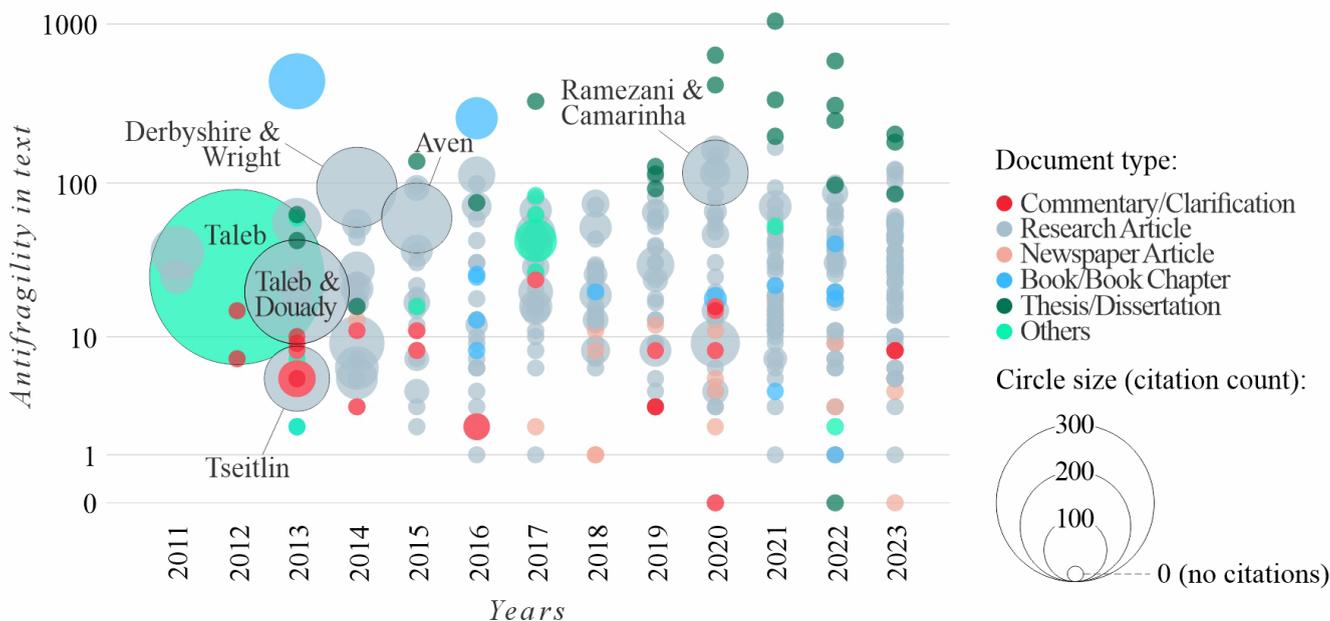
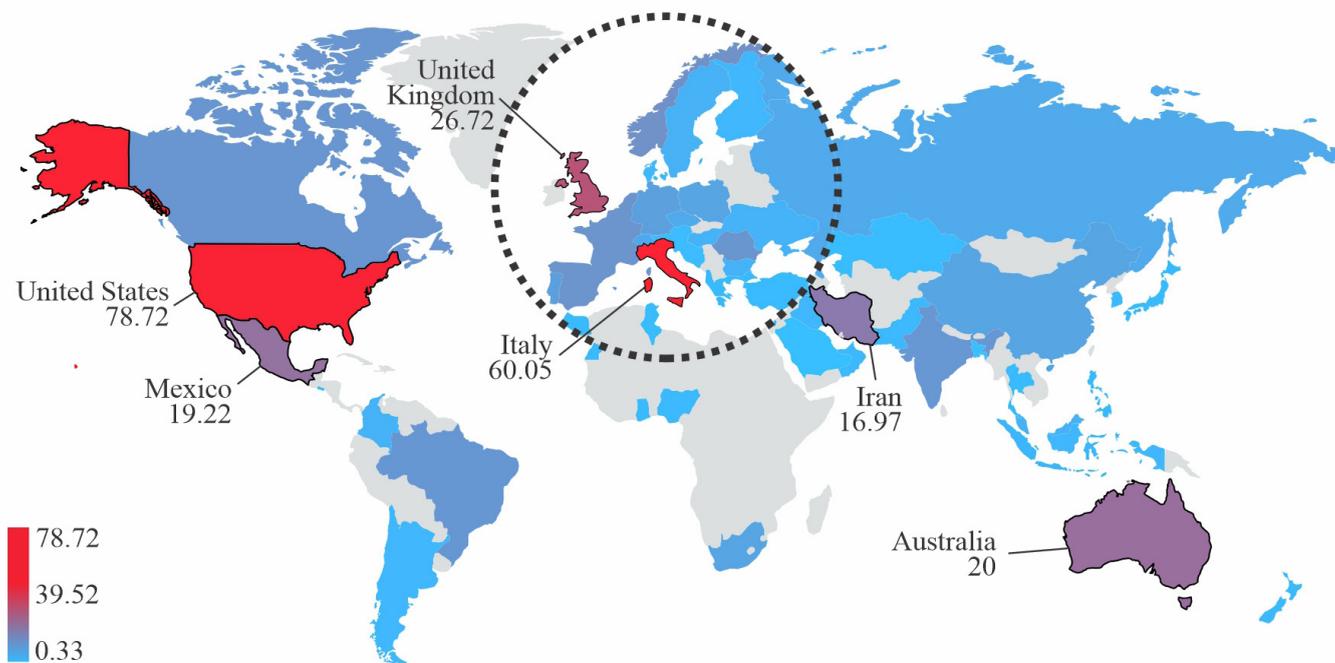
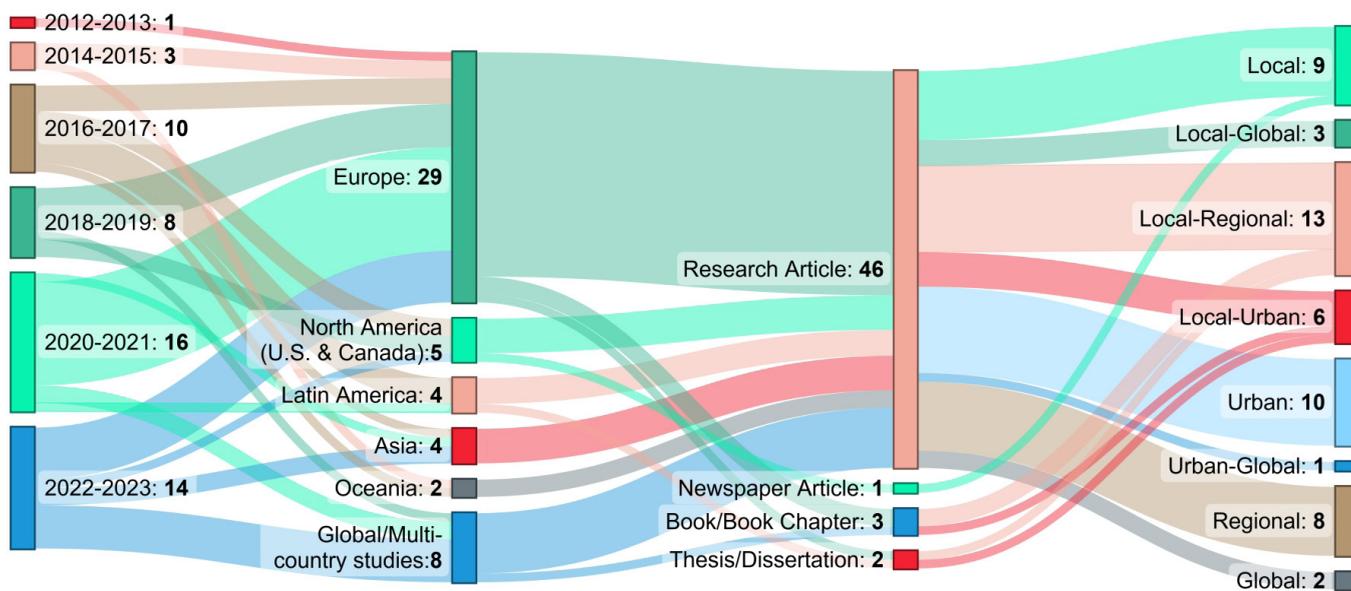


Figure 3. Antifragility mentions across document types over time  
Source: Authors.



**Figure 4.** Origin of registries by fractional count of authors per document  
**Note.** Labels show countries in the top 10% (n = 489; 38 with no country, 12 invalid).  
**Source:** Authors.



**Figure 5.** Distribution of selected documents across periods, regions, types, and scopes  
**Note.** Scope refers to the spatial scale(s) addressed in each document (local includes micro/architectural; regional includes national).  
**Source:** Authors.

Year	Authors	Thematic focus	Spatial scale
2023	Redmond et al.	Presents a framework on urban ecosystems.	Urban
2023	Altun et al.	Analysis of the Advanced Future Mobility Air Traffic Network.	Regional
2023	Jaffe et al.	Adaptation of pre-Hispanic indigenous people of Peru to the El Niño phenomenon.	Regional
2023	Axenie	Antifragile control systems for urban traffic dynamics.	Local
2023	Toorop & López	Assessing the adaptability and vulnerability of small farmers in Bihar, India.	Local
2023	Dezio & Paris	Territorial governance and design in rural areas.	Local and Regional
2023	Ji et al.	Cognitive communication networks with multiple relays and antifragile relay communication for intelligent transportation systems.	Transportation system and communication networks
2023	Gkoumas et al.	Resilience-based design and political decision-making.	Local and regional
2022	Cerasoli et al.	Sustainable urban mobility strategies in the post-COVID context.	Micro (local) and macro (urban)
2022	Goodwill et al.	Incorporating antifragility into water treatment systems.	Local and global
2022	Galimberti	Preparation, care, and antifragility in urban planning.	City, community and individual
2022	Pasqui	The concept of "antifragility" as a tool for urban and territorial planning.	Local, regional and national
2022	López	Planetary antifragility.	Global
2022	Notarstefano	Measuring the antifragility of territories through active and passive sustainability.	Local
2021	Argenziano et al.	Vertical extensions of masonry-built heritage for sustainable and antifragile urban densification.	Local and regional
2021	Sartorio et al.	Development of a research agenda to advance resilience and antifragility in the built urban environment.	Urban
2021	Dezio et al.	Rehabilitation of unused buildings for "slow tourism" in vulnerable areas.	Local and regional
2021	Shearer et al.	Conceptualization of an antifragility model for dense urban areas.	Urban
2021	Oppio	Evaluation of regeneration policies and strategies in inland areas from a multicultural perspective.	National
2021	Dezio	Storytelling and cultural heritage as an antifragile tool.	Local and regional
2021	Lomas-Rodríguez	The mountain as a sacred space and its relationship with architecture and phenomenology.	Micro (architectural project)
2021	Houbart & Verbeeck	The importance of critical reflection in the field of conservation and restoration.	General
2021	Nieuwborg & Hiemstra	Design of an antifragile methodology for managing health interruptions in multimodal transportation hubs.	Global
2021	Galimberti	Reflection on uncertainty in a world of interconnected local and global crises.	Local
2021	Kibaroglu	The antifragility of popular economies and digital urban infrastructure in Indonesia.	Micro (individual) and meso (community)
2021	González-Tejeda	Seismic risk management using the concept of antifragility.	Local
2021	Galimberti	Antifragile strategies in urban design.	Continental (Europe)

Year	Authors	Thematic focus	Spatial scale
2020	Blečić & Cecchini	Antifragility in urban planning.	Urban
2020	Dezio	Reconceptualization of rural heritage as antifragile territorial capital.	Local and regional
2020	Timashev	Antifragility and supra-resilience of critical urban infrastructures.	Municipal
2019	Blečić & Cecchini	Antifragility as an objective for urban planning.	Urban-territorial systems
2019	Rodríguez	The city as a complex system and the opportunity to incorporate entropy and adaptability into its planning.	Local and urban
2019	Roggema	Antifragile landscape design in coastal areas and deltas.	Local and regional
2019	Galimberti	Antifragile design of open urban spaces in Europe.	Local
2019	Galimberti	Antifragile practices for designing social dialogue in contemporary European public spaces.	Macro
2018	Babovic et al.	Antifragility applied to water infrastructure systems in cities.	Urban scale
2018	Lunemann et al.	Evaluating New Jersey's Response to the Impact of Hurricane Sandy on Navigation Channel Maintenance.	State
2018	Brownell	Antifragile construction and architectural materials.	Local
2017	Blečić & Cecchini	The antifragility of cities and their buildings.	Urban and architectural
2017	Hespanhol	Building antifragile cities through the use of digital technologies.	Local and regional
2017	Las Casas & Scorza	Rational renewal of urban and territorial planning.	Local and regional
2017	Gutiérrez	Resilience and antifragility in housing typologies.	Regional
2017	Shafique	The need for a utopian approach to urban and architectural planning.	Local and global
2017	Munjin-Paiva	Practical application of the concept of antifragility in architecture.	Micro (architectural systems) and macro (urban environment)
2016	Marchigiani	Sustainable and resilient urban planning in the city of Trieste, Italy.	Local and regional
2016	Paiva	The search for antifragile architecture.	Micro (architecture)
2016	Shafique	Antifragility in urban planning	Urban systems and global environment
2016	Schwake	Antifragile regeneration processes in neighborhoods in Israel.	Urban
2015	Sorensen	Antifragility, stable adaptation and future-proofing in Australia's regional development.	Macro (regional) and micro (business and individual)
2015	Gkouma et al.	Considerations from civil engineering in the built urban environment.	Urban
2014	Guang et al.	Development of antifragile processes for public cloud services.	Urban computing ecosystem
2013	Mathé	Hida-Furukawa region in Japan from an economic and political geography perspective.	Local and regional

Table 2. List of selected research papers

Source: Authors.

Before exploring the dimensions of urban antifragility, it is necessary to examine its meaning and its application in urban planning, drawing on research published between 2011 and 2023, after Taleb introduced the concept of antifragility (2013, p. 25).

Antifragility, according to Taleb, is the

[...] potential gain [...] from exposure to something related to volatility. What is that something? Simply, membership in the extended disorder family: 1. Uncertainty; 2. Variability; 3. Imperfect, incomplete knowledge; 4. Chance; 5. Chaos; 6. Volatility; 7. Disorder; 8. Entropy; 9. Time; 10. The unknown; 11. Randomness; 12. Turmoil; 13. Stressor; 14. Error; 15. Dispersion of outcomes; [and] 16. Unknowledge. (Taleb, 2013, p. 36)

The analyzed authors proposed and adapted the concept of antifragility for each context and in some cases provide contributions based on other definitions. These parallel concepts comprise about 70. The top ten most mentioned were: Antifragility (General), Urban Antifragility, Antifragile System, Antifragile Planning, Antifragile Architecture, Antifragile Urbanism, Antifragile Utopia, Supra-resilience, Antifragile Buildings/Antifragile Design and Antifragile (Urban) Development.

Without being restrictive, the scales identified in the analyzed studies were classified according to the scale of the units or objects under study as follows: (1) micro scale (architecture, civil engineering, critical infrastructure), (2) local (streets, slums, neighborhoods, tourism), (3) urban (mobility, infrastructure networks, sectors, districts), (4) territorial (connectivity, ecosystems, eco-tourism), (5) national (states, regions), and (6) global (continents, planetary level). However, many of the characteristics can be shared between levels.

A word frequency analysis (NVIVO) examined over 500 citations on characteristics of the concept, then semantically grouped. As a result, 19 characteristics are proposed for the concept of urban antifragility summarized in the following 5 analysis dimensions.

Dynamic configuration (reconfiguration capabilities): (1) adaptation and anticipation, (2) flexibility and optionality, (3) autonomy and self-organization, (4) self-repair and recognition of vulnerabilities, and (5) emergence and unpredictability.

Synergic processes (interaction capabilities): (6) creativity and innovation, (7) experimentation and risk, (8) regeneration and transformation, and (9) fractality, organicity and aesthetics.

Strategic governance (guidance framework): (10) participation and community, (11) Ethics, equity and equality, (12) Exclusion and laxity, and (13) Networks and context sensitivity

Epistemic management (sense-making capacities): (14) planning and vision, (15) information and knowledge, (16) observation and monitoring, and (17) intelligence and learning

Systemic development (developmental orientation): (18) benefits and gains, and (19) transcendence and self-improvement.

In Table 3 the indicators for assessing antifragility (n=26) proposed and reviewed by the authors can be consulted.

## Discussion

Other sources or dimensions of urban antifragility may exist, as the concept remains under development. The systematic review also aims to provide construct validity to the concept of urban antifragility, thereby enabling its theoretical approach. This framework addresses elements corresponding to three conceptual domains: Stressors (disorder family), sources or dimensions, and urban theories or models.

In Table 3 is possible to see that the indicators suggested by the authors are related with one or a combination of the 19 characteristics of urban antifragility proposed herein.

### Implementation as a conceptual framework

A theoretical overlap of antifragility with the concept of resilience was found in the literature, as some authors relate antifragility to a “process of continual adaptation” (Babovic et al., 2018, p. 4). Resilience is also related to improvements in a system after exposure to stress (Chiffi & Curci, 2024, p. 19). In one of the analyzed studies, from a landscape architecture viewpoint, adaptability was one of the three dimensions used by the authors (Roggema, 2019, p. 115).

According to the authors, the fundamental difference lies in the fact that resilience requires no fundamental changes to the structure or function of the system to be achieved (Chiffi & Curci, 2024, p. 19). Antifragile systems tend to remain in uncertain situations, beyond the system that is resilient; additionally, they have the ability to

turn threats into fuel for their own growth (Galimberti, 2021, p. 7; Chiffi & Curci, 2024, p. 20). This may sound contradictory but being unaware of such dangers is also a source of advantage for an antifragile system (Galimberti, 2019, p. 3131).

Likewise, disinformation encourages deep learning. This process generates new information that helps the antifragile system move forward from mistakes (Galimberti, 2019, p. 3138; Sartorio et al., 2021, p. 141; Blečić & Cecchini, 2019, p. 495). Learning comes not only from unexpected error, but from controlled fault, where the system “advances via trials-and-errors” (Blečić & Cecchini, 2019, p. 495; Adelhart Toorop et al., 2023, p. 14).

Moreover, antifragility enables, under the influence of a stressor, the possibility of “selection and removal of weaker system features and allowing the system to evolve toward a better state” (Adelhart Toorop et al., 2023, p. 3).

Self-repair is also part of antifragile systems, in contrast to those requiring continuous maintenance (Babovic et al., 2018, p. 5; Mathé Hesby, 2013, p. 50), but, according to the authors, it is not a strong attribute. However, this property is very difficult to achieve, especially in inert systems, such as the example of the trousers proposed by Timashev:

If I buy a pair of Levi’s jeans a couple sizes larger than my current waist and then wear them until I feel them tight on me, I cannot claim that these jeans all the time were antifragile. In order to be antifragile they must adjust by themselves, without human intervention, to the size of my waist and self-repair, if need be. (2020, p. 5)

Also, self-organization is a condition of an antifragile system (Notarstefano, 2022, p. 176; Adelhart Toorop et al., 2023, p. 1; Equihua et al., 2020, p. 3; Shearer et al., 2021, p. 77). The capacity to organize after a hazard event is a property related to survival.

Antifragility exhibits the characteristic of being an evolutionary (Munjin Paiva & Pfenniger B., 2017, p. 12; Lomas-Rodríguez, 2019, p. 7), temporal (Timashev, 2020, p. 4) and ubiquitous process (Pasqui, 2022, p. 69). Namely, antifragile systems develop over time and space in a manner that is configured to ensure benefits.

To enable evolution, optionality is an important characteristic identified by many authors as part of the concept of antifragility (Munjin Paiva, 2016, p. 92). This means that the development of the system is supported by the solutions it has when a crisis occurs. Redundancy is a “particular - simple - case of optionality” (Galimberti, 2019, p. 3141) and is also a viable method to ‘reduce exposure to shock’ (p. 3131).

Based on the essential features of the concept and the collected definitions, the following specific definition of antifragility is proposed: Theoretical quality, attribute or non-predictive internal organic process of a system, structure, individual or object, which is conditioned to the frequency, magnitude and uncertainty of stressors to which it is exposed over some period of time, and results in a potential benefit with characteristics of self-improvement, self-repair, adaptation and/or transformation, exploiting mechanisms such as optionality, self-organization, capacity for election and self-learning, or even the vulnerability of its own components or constituents.

Currently, the implementation of the concept of antifragility in architecture, urban planning and territory fields is insufficient (Nieuwborg et al., 2021, p. 394). The proposal offered by Aven (2015), mentioned by Gkoumas et al., to assess antifragility is to use asymmetry, namely, “the idea that if a random effect has more upside effects than downside effects, [then] is antifragile” (2022, p. 131).

Therefore, the authors propose the following definition of urban antifragility in the framework of the previous specific definition: Urban antifragility is the positive balance between quantitative and qualitative, tangible, and intangible benefits and harms that an urban system obtains under conditions of volatility or stress, considering the characteristics and behavior of its components.

### Urban antifragility indicators

Theoretically, indicators listed in Table 3 present a presence-latency-absence relationship according to the proposed dimensions of urban antifragility. Consequently, unslumming, a term used by Jane Jacobs to address the process of deprecarization of marginalized neighborhoods and the design of new urban communities (Blečić & Cecchini, 2020, p. 8), it is the index that provides clearest evidence of urban antifragility, as it deals with aspects such as adaptation, autonomy, creativity, emergence, etc. This result supports Taleb’s affirmations when he mentions Jane Jacobs as a heroic New York activist with antifragile proposals versus Le Corbusier or the urbanist Robert Moses (Taleb, 2013, p. 51; Munjin Paiva, 2016, p. 94).

Although Jane Jacobs does not mention antifragility per se, she identifies factors that Taleb later conceptualized as part of the “disorder family”. Jacobs distinguishes chaos from complexity (1961, p. 257). She also offers indicators for urban diversity, corresponding to a term that is subsumed under optionality. Jacobs’ principles of diversity are: (1) covering more than one function per district; (2) adequate block sizes; (3) sufficient compactness and mix of buildings from different historical periods; and (4) population density (p. 182).

	Index/indicators	Authors	Related concept	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
				Score >																				
				6.5	6	8.5	6.5	10	7	0.5	5	1	2.5	2.5	3.5	2.5	6.5	6.5	11.5	4	4	5		
1	Increased diversity, density, place-based engagement, gradual investment	Jacobs* mentioned in Cozzolino	Unslumming	█		█	█	█			█		█	█		█	█					█	9.0	
2	Care (Passive Sustainability)	Notarstefano	Antifragile sustainability	█	█	█					█				█		█	█	█			█	8.0	
3	Custody (Active Sustainability)	Notarstefano	Antifragile sustainability	█			█		█						█		█	█	█			█	6.5	
4	Antifragility Assessment of Complex Adaptive Systems	Johnson & Gheorghe	Antifragility		█	█	█	█				█							█	█			6.5	
5	Principles of antifragile planning	Blečić & Checchini	Antifragile Planning			█	█	█								█	█					█	6.0	
6	Community Antifragility	Mathé	Satoyama	█	█	█											█	█	█				6.0	
7	Territorial Attractiveness (cycling and pedestrian routes) and Territorial Vulnerability	Dezio et al.	Sustainable Tourism	█	█			█	█							█		█	█				5.5	
8	Antifragile Vertical Extension (architectural language, urban context, seismic response)	Argenziano et al.	Seismic Antifragility	█							█		█	█				█					5.0	
9	Decision-making with real-time risk-based prediction	Redmond et al.	AntifragiCity (Urban Mobility)											█				█	█		█	█	4.5	
10	Political-Military-Economic-Social-Infrastructure-Information Framework (PMESII)	US Army (Shearer et al.)	City as a Natural-Human System		█						█						█			█			4.0	
11	Analysis of the flight and port network	Altun et al.	Future advanced air mobility		█		█											█	█			█	4.0	
12	Changes in Ecosystem Complexity	Equihua et al.	Ecosystem Antifragility			█	█											█	█			█	4.0	
13	Gain or Loss of Optionality	Shearer et al.	Urban Antifragility		█						█							█		█			3.5	
14	Storytelling and Pedagogical Maps as an Antifragile Tool	Dezio	Cultural Heritage							█			█	█	█		█		█				3.5	
15	Stock accumulation, creation of optionality and strengthening autonomy	Toorop et al.	Antifragility in Agricultural Systems			█		█	█								█	█			█		3.0	

	Index/indicators	Authors	Related concept	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
16	Choice + Optionality (Asymmetry + rationality)	Taleb*	Antifragility			█		█											█				3.0
17	Antifragile Behavior (intensity)	Munjin-Paiva & Pfenniger	Intangible Antifragility			█	█	█			█												3.0
18	Principles of equity, effectiveness, and conservation of unsupported resources	Las Casas & Scorza	Antifragile Strategies and Tactics		█										█		█					█	2.5
19	Antifragility = Resilience + Over-compensation	Timashev	Urban Supra-resilience	█					█														2.0
20	Optionality	Sorensten	Regional Economic Antifragility					█	█														2.0
21	Exposure to Disorder (Fragile-Robust-Antifragile)	Estudio abierto/ Open Studio	Urban Antifragility					█	█														2.0
22	Anomalies in the Earth's albedo	López-Corona et al.	Ecosystem Antifragility																█		█		1.5
23	Application of Physicochemical Processes (knowledge and evaluation)	Goodwill et al.	Antifragility in Water Treatment																█		█		1.5
24	Damage (qualitative/comparative) caused by a Shock	Aven	Asymmetry (proposed by Taleb)						█														1.0
25	Fragility is estimated	Taleb*	Antifragility						█														1.0
26	Flexible-Rigid	Munjin-Paiva & Pfenniger	Antifragile Architecture					█															1.0

Table 3. Indicators used to assess urban antifragility

Note. \*Authors cited in papers. Symbology: Dynamic configuration: A = Adaptation and Anticipation; B = Self Repair and Recognition of Vulnerabilities; C = Autonomy and Self Organization; D = Emergence and Unpredictability; E = Flexibility and Optionality; Systemic development: F = Benefits and gains; G = Transcendence and Self-improvement; Synergic processes: H = Creativity and Innovation; I = Experimentation and Risk; J = Fractality, Organicity and Aesthetics; K = Regeneration and Transformation; Strategic governance: L = Ethics, Equity and Equality; M = Exclusion and Laxity; N = Participation and Community; O = Networks and Context Sensitivity; Epistemic management: P = Information and Knowledge; Q = Intelligence and Learning; R = Observation and Monitoring; S = Planning and Vision; T = Score per index /indicator. Black = Explicit mention (1 point); Gray = Latent presence (0.5 point).

Source: Authors.

Jacobs is also critical of top-down projects, due to the fact that its development is “all at once and without too much space for spontaneity and further reinterpretations” (Cozzolino, 2018, p. 22), which makes the urban fabric rigid and inflexible. According to Taleb, urban iatrogenesis can be caused by the consequences of urban planning: “urban blight, inner cities, depressions, crime” (2013, p. 155). In this context, both authors agree.

Second, we find the term “care” proposed by Giuseppe Notarstefano (2022, p. 176). Notarstefano argues that sustainability consists of two domains: “care (passive sustainability) and custody (active sustainability)” (2022, p. 176).

According to Notarstefano, the concept of care comprises 8 of the 17 Sustainable Development Goals (SDGs). These concern poverty, hunger, health, education, equality, clean water, and life (Notarstefano, 2022, p. 176).

Similarly, the concept of custody proposed by Notarstefano (2022, p. 177) has antifragile affinities and appears in third place. According to the author, as part of active sustainability, the term includes SDGs that focus on clean energy, work, industry, inequality, sustainability, climate, among others. The conclusion of Notarstefano’s proposal is that the SDGs are an instrument that brings anti-fragility to the city and the territory (ONU, 2016).

Ranked fourth in the list is the Complex Adaptive Systems Antifragility Assessment. This instrument provides an analysis measuring on a Likert scale each attribute of the systems assessed (Johnson & Gheorghe, 2013, p. 164).

The instrument contains criteria used to analyze the smart grid of the US energy system, through a scale on a range from -10 to 10 that represents a fragility index indicating whether the system is fragile, robust or antifragile (Johnson & Gheorghe, 2013, p. 165). This perspective mentions some of the factors that Taleb calls the “disorder family” (2013, p. 36) such as entropy and stress, and in a latent way relates to chaos and disorder.

In the fifth position Blečić and Cecchini (2019) introduced the application of the concept of antifragility to urban planning regarding two aspects: (1) applying antifragility to the purpose of planning and (2) applying antifragility to planning itself (p. 492).

Personally, the authors have identified those characteristics that make planning fragile, consisting of: “(1) plans and policies based on fragile predictions, (2) excess of centralization-cum-micromanagement, (3) efficiency and optimization, (4) specialization, (5) simplification and standardization, and (6) lack of consensus building, and the crumbling of the ‘cement of society’” (Blečić & Cecchini, 2019, p. 492).

The authors logically suggest that antifragile planning should embrace the opposite aspects of fragile planning and propose three approaches to be considered: (1) *via negativa*, (2) a shared vision, and (3) project space.

Via negativa under the authors’ planning perspective corresponds to the reduction of excessive and detrimental urban instruments that constrain a more coherent development of cities without succumbing to minarchism (p. 494). Contrastingly, the shared vision identifies which future scenarios to avoid and which strategies to consider (Blečić & Cecchini, 2017, p. 7). The *project space* is defined by the authors as the *via positiva* in which

“plans and regulations should allow for the free expression within the social forms they chose” (p. 7), limited by *via negativa* and by the shared vision (Blečić & Cecchini, 2020, p. 14).

In sixth place, the Community-based antifragility<sup>[3]</sup> by Daniel Hesby Mathé appears. The author studies Satoyama: Mountain villages in Japan. The analysis is presented from a qualitative approach based on retroduction during “the process of constructing representations from the interaction between analytical frames and images” (Ragin & Amoroso, 2011, p. 76).

In addition to observation, the author employed semi-structured interviews (Mathé Hesby, 2013, p. 56), which lasted from 35 minutes to one hour (p. 62), as an instrument for collecting information. The interviews covered general topics, such as harvesting, municipal-regional relations, economic circumstances, and public policy practices in relation to satoyama (p. 109).

The seventh position corresponds to attractiveness and territorial vulnerability by Dezio, Dell’Ovo and Oppio. The authors proposed “a hybrid methodological approach based on the combined evaluation of territorial attractiveness and vulnerability [...] [using] Multicriteria Analysis (MCA) in the Geographic Information Systems [...] [for] the identification of disused buildings suitable for adaptive reuse” (Dezio et al., 2021, p. 1819).

The analytical framework is multidimensional based on four phases around the concept of sustainable tourism: (1) territorial strengths to generate attractiveness maps, (2) territorial weaknesses for mapping vulnerability, (3) characterization of public cultural assets, and (4) selection of interventions based on maximization of strengths, budget constraints and consistency with the concept goals (p. 1821).

As the latest instrument emphasized, Argenziano et al.

[3] Named for this research.

(2021) propose the antifragile vertical extension in masonry buildings, as a response to the needs for new inhabitants in cities without available space in Italy (p. 2). As a novel element, the technique of rooftop construction using seismic isolation in combination with architectural and structural considerations is proposed (p. 2).

The architectural approach comprises the location of the buildings and the dialogue of the new design with the urban environment and is integrated by the identification of three structures: (1) the original building structure, (2) the isolation system, and (3) the new upper metal structure (p. 8). Similarly, the instrument encompasses an extensive parametric analysis to minimize the seismic response (p. 9). The proposal addresses antifragile dimensions such as adaptation, innovation and creativity, aesthetics, context sensitivity, and urban regeneration.

## Conclusion

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A systematic literature review enables the synthesis of extensive research findings across studies. Nevertheless, urban antifragility remains an emerging concept, characterized by significant theoretical, practical, and methodological gaps. The challenges associated with the 'disorder family' call for holistic and complexity-oriented approaches. Thus, this research should contribute to enhance such an integrative perspective.

Furthermore, moving from the theoretical discourse to the employment of indicators in the assessment of urban, territorial and architectural antifragility allowed the observation of the following considerations: (1) information and knowledge, and autonomy and self-organization as necessary requirements of urban antifragility were less mentioned by the analyzed authors, although highly invoked; (2) flexibility and optionality kept their relevant role consistently with theory; and (3) multiple characteristics exist that can provide antifragility but have been ignored, such as experimentation and risk, exclusion and laxity, and fractality, organicity and aesthetics.

An additional finding in the field of urban antifragility is that multi-country studies emerge later, alongside ongoing publications from other regions, suggesting a trend toward integration without fully replacing region-specific studies. European studies, however, maintain a consistent presence and remain central in the research.

Nevertheless, additional research is needed to empirically examine antifragility in architectural, urban, and territorial contexts and to strengthen its conceptual foundations. In this regard, this systematic literature review

synthesizes how the concept of antifragility has been addressed in these fields, with the aim of defining its conceptual scope and supporting the development of new strategies applicable to socio-ecosystems exposed to high levels of stress and vulnerability.

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