Fragility and Antifragility in Cities and Regions

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Space, Uncertainty and Inequality

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Edward Elgar
PUBLISHING

Cheltenham, UK • Northampton, MA, USA

Cover image: Operational landscapes in Sardinia by Davide Simoni

Published by
Edward Elgar Publishing Limited
The Lypiatts
15 Lansdown Road
Cheltenham
Glos GL50 2JA
UK

Edward Elgar Publishing, Inc.
William Pratt House
9 Dewey Court
Northampton
Massachusetts 01060
USA

A catalogue record for this book
is available from the British Library

Library of Congress Control Number: 2023948698

This book is available electronically in the Elgaronline
Geography, Planning and Tourism subject collection
http://dx.doi.org/10.4337/9781035312559

ISBN 978 1 0353 1254 2 (cased)
ISBN 978 1 0353 1255 9 (eBook)

Contents

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Acknowledgements

This book stems from the DAStU 'Fragilità Territoriali' (TF) Research Project funded by the Italian Ministry of Education, University and Research (MIUR), Departments of Excellence Initiative 2018–2022 (https://www.eccellenza.dastu.polimi.it/en/). We would like to express our gratitude to all the referees who have played a valuable role in enhancing the overall quality of this book.

1. Disentangling antifragility from resilience[1]

Daniele Chiffi and Francesco Curci

1.1 INTRODUCTION

Architecture, urban policies and planning are based on the need to prefigure and encourage possible changes that contribute to the construction of 'desirable futures' (the world as we would like it to be); let us call this 'the wishful stance'. This objective can be achieved, on the one hand, thanks to the analysis of past and present phenomena and situations (the world as it was and as it is); let us call this 'the descriptive stance'. Or, on the other hand, thanks to the ability to deal with different and constantly changing possible future scenarios (the world as it will be or could become); let us call this 'the future stance', trying to modify them in accordance with specific values and goals. Simply 'knowing the world as it is' is not enough, of course, to infer 'the world as we would like it to be'. Still, beyond these limitations, what we can do to reduce the gap between the descriptive stance and the wishful stance is to focus on the 'future stance' and the possibility of adhering to it. We think that architecture and urban studies can greatly contribute to shaping the future of our cities and regions. Specifically, urban and regional planning is mainly directed towards some desirable future scenarios envisaged in accordance with specific goals, values and methods, and characterised by different forms of uncertainties. Even if uncertainty may be considered something particularly undesirable,

[1] This work is supported by: (1) the Excellence Project 'Fragilità Territoriali' (2018–2022; L. 232/2016) of the Department of Architecture and Urban Studies (DAStU; Politecnico di Milano); (2) RIBA project 'Norms, Uncertainty and Space (Nous): Cities in The Age of Hyper-Complexity' (DAStU; Politecnico di Milano); (3) RETURN Extended Partnership, Multi-risk science for resilient communities under a changing climate, European Union Next-GenerationEU (National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investment 1.3 – D.D. 1243 2/8/2022, PE0000005); (4) Italian Ministry of University and Research under the PRIN Scheme (Project no. 2020SSKZ7R). We thank Stefano Moroni and Luca Zanetti for their remarks on a previous version of this chapter.

it is important to clarify that without uncertainty there would be no need to innovate and plan, in the sense that uncertainty is one of the main triggers of progress and one of our doors to the future (Chiffi et al. 2022; Moroni and Chiffi 2021).

In addition to the pivotal issue of uncertainty, many key related notions are connected in urban and regional studies with the possibility of planning desirable futures, namely risk, fragility, vulnerability, resilience and antifragility.[2] In this chapter, we assume fragility as a hallmark of contemporary urban and regional systems, which should not be collapsed into the notion of vulnerability in risk analysis. Likewise, we critically discuss the dangers of collapsing the recently introduced notion of antifragility into any type of resilience. We hold the view that a conceptual clarification of all these terms may have a deep impact at both the methodological and policy levels when dealing with new sociospatial challenges and inequalities. Section 1.2 explores the relations between the concepts of risk and uncertainty, while section 1.3 critically discusses the notion of fragility.[3] Section 1.4 focuses on the conceptual and methodological differences between different forms of resilience and antifragility and their implications for urban and regional studies. Finally, section 1.5 concludes the chapter.

1.2 RISK AND UNCERTAINTY

Given its nature, the adoption of the concept of fragility in urban and regional studies can hardly be explained without referring to the main elements of risk analysis and studies on uncertainty. For this reason, we focus first on the main elements of risk and then on recent research on types of uncertainty in decision-making to provide a suitable framework within which to interpret fragility.

1.2.1 Understanding Risk

The first notion that we consider is the concept of risk. When referring to risk, many different definitions are implied, some informal and some more technical. Moreover, the concept of risk may have different meanings and conceptualisations among different disciplines and even within the same field.

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[2] Although the concept of antifragility was introduced by Taleb (2012), our use of this concept and allied notions is not an analysis or interpretation of Taleb's views.

[3] The reflections presented in sections 1.2 and 1.3 were developed for the first time in our previous publications, Chiffi and Curci (2022) and Chiffi and Curci (2020), respectively.

In probabilistic risk assessment, a classic (and technical) definition is the one given by the Royal Society, according to which risk is a function of the probability of an event, the magnitude of its effect and the severity of the consequences in a stated period (Royal Society 1983). This is a probabilistic and consequentialist definition of risk, since its two main ingredients are the probability of the unwanted event and the severity of its consequences. Therefore, risks with high probability and small consequences are equivalent to risks with low probability and severe consequences. However, other definitions can also be found in the literature. For instance, risk can be understood as: (1) an unexpected event that may or may not occur; (2) the cause of an unexpected event that may or may not occur; (3) the probability of an unexpected event that may or may not occur; (4) the expected statistical value (that is, the product of the probability and a severity measure) of an event that may or may not occur – this is essentially the definition given by the Royal Society; and (5) the fact that a decision was made under known conditions of probability (known unknowns); see Hansson (2022a; Roeser et al. 2012).

Definition (1) only stresses the unexpected nature of a risky event, while (2) identifies the cause of an event with the risk itself. Of course, it is one thing to talk about risk factors, but quite another to be able to distinguish between risk and cause, which can often become extremely misleading. Definition (3) highlights the random character of a risky event, regardless of the potential impact of the consequences of such an event. Quite contrarily, (4) includes, in the definition of risk, the assessment of possible consequences. The last definition, (5), stresses how decisions taken under risk conditions fall within the scope of known unknowns; that is, of those events that may or may not occur, and of whose potential occurrence we have at least a probabilistic assessment.

In the field of disaster risk assessment, in particular, the following are identified as risk components: the potential danger (or hazard), the exposed value (or exposure), and the vulnerability, which can be defined as the susceptibility of the exposed elements (people, manufactured products, economic activities, and so on) to suffer damage caused by a specific potentially harmful event (UNISDR 2015; Balducci et al. 2020). Understanding the sources of risk by means of its three components is particularly relevant for policy-based considerations of risk mitigation, since an understanding of the specific nature of the risk can help the experts to mitigate the hazard or the exposure, and possibly also reduce the vulnerability.What many of the different definitions of risk have in common is an evaluative and normative component that contributes to the multidimensionality of the concept.

1.2.2 Reflections on Uncertainty

The second notion that we consider is uncertainty. As we have seen, we can technically speak of (probabilistic) risk when we are able to both estimate the expected value of a possible event from a probabilistic point of view – since elements such as its statistical distribution are known – and to evaluate its possible consequences in a stated period. A well-known example of a decision taken under conditions of risk is that of betting on roulette at a casino: here, all the probabilities of an event are computable *ex ante*. When this is not possible, we speak generically of uncertainty, which in the most severe forms is called severe uncertainty (unknown unknowns) or even ignorance (Carrara et al. 2021). Severe uncertainty (also known as fundamental, genuine, deep or great uncertainty) has a nonprobabilistic nature and represents the most common form of uncertainty that we experience in everyday life. Keynes makes this concept clear by stating that:

> By 'uncertain' knowledge I do not mean merely to distinguish what is known for certain from what is only probable. The game of roulette is not subject, in this sense, to uncertainty ... The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence ... About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know. (Keynes 1973: 213–214)

According to Keynes's perspective, it can be difficult to give a probabilistic risk assessment of deeply uncertain events that we have (almost) never even considered. It is exactly in these cases that we speak of uncertainty. In the following section, we clarify the reasons that we believe fragility adheres more to notions related to forms of uncertainty than to risk.

Together with the related concepts of risk and ambiguity, uncertainty has long been a key concept in psychology, economics, decision-making and planning processes (Lipshitz and Strauss 1997). In particular, urban problems are usually shaped by different forms of uncertainty and complexity and are the prototypical example of so-called wicked problems (Rittel and Webber 1973), which are often dealt with in planning theories. The term 'wicked' points to complex and 'malicious' dilemmas that can only be fully expressed and understood after the formulation of their solution; in turn, a solution will be difficult to formulate due to the problem's uniqueness and the poorly defined aspects involved. In other words, to anticipate any questions arising from wicked problems, it is necessary to have knowledge of all possible solutions. Urban problems – with their multifaceted structures and ways of interacting with other complex and scarcely defined systems – seem to belong even more to this family of problems. Given their complexity, we hold the view that to properly cope with them, it is important to disentangle the different types of uncertainty that shape a wicked problem. In this way, the planner may understand the nature of the uncertainty involved in the problem and suggest potential strategies to cope with it.

1.2.3 Types of Uncertainty

Uncertainty comes in different forms, and a few studies have proposed specific taxonomies based on the various factors that contribute to its formation, management and treatment, especially with respect to decision-making and planning processes. We discuss some interesting classifications and conceptualisations that may help us to understand the specific features of uncertainty present when making decisions about cities and regions. An initial taxonomy is based on the analysis of hundreds of decision-making self-reports and differentiates three main causes of uncertainty: inadequate understanding, incomplete information and undifferentiated alternatives (Lipshitz and Strauss 1997). Inadequate understanding may depend on equivocal information due to novel, fast-changing or unstable situations. Incomplete information may depend on a partial or complete lack of information or unreliable information. The third cause of uncertainty (undifferentiated alternatives) refers to the fact that, even when information is perfect, decision-making can be affected by the conflict among alternatives owing to equally attractive outcomes or to incompatible role demands.

A second taxonomy is founded on the nature and object of uncertainty (Bradley and Drechsler 2013). According to Bradley and Drechsler, the nature dimension relates to the kind of judgement being made. In this case, it is possible to distinguish three forms of uncertainty: modal uncertainty about what is possible or what could be the case, empirical uncertainty about what is the case (or has been or would be the case), and normative uncertainty about what is desirable or what should be the case. The object dimension relates to the features of reality towards which agents' judgements are directed. Here, it is possible to distinguish two forms of uncertainty: factual uncertainty about the way things are now, and counterfactual uncertainty about the way things could or would be if things were other than the way they are.

Furthermore, in attending to dynamically adaptive systems, some authors have proposed taxonomies based on the sources of uncertainty across the three distinct levels of the management and decision-making process: the requirements level, the design level and the run-time level (Ramirez et al. 2012). Uncertainty at the first level is owed to the idealisation, misunderstanding and incompleteness of functional and nonfunctional requirements (e.g., missing or ambiguous requirements, falsifiable assumptions). The second level is uncertain, primarily due to unexplored alternatives and untraceable design.

Uncertainty in the third phase occurs primarily because of environmental unpredictability.

A comprehensive and transversal taxonomy that partially embraces previous proposals has been outlined recently by Hansson (2022b), and for a critical discussion in the context of post-pandemic cities, see Chiffi and Curci (2022). According to this taxonomy, we can list the following types of uncertainty:

1. Factual uncertainty. This uncertainty surrounds the facts of the physical world and may usually be quantified and formalised.[4]
2. Possibilistic uncertainty. This form of uncertainty concerns what can possibly be known. In this case, uncertainty depends on many factors, such as: (a) the constraints on the information that an agent may obtain in a specific context at a given time; and (b) the very nature of the decision, which may deal with forms of logical, physical, biological and social possibility.
3. Metadoxastic uncertainty (or uncertainty of reliance). Our beliefs may be uncertain. This uncertainty is a second-level judgement about the accuracy of one's beliefs and is expressed, for instance, by second-order probabilities or confidence intervals.
4. Agential uncertainty. This type of uncertainty considers individual future decisions and actions. It cannot be formalised or quantified, as there is no suitable decision method. For instance, there is no proper methodology to formalise or compute the consequences of whether one will get married in two years. This uncertainty is thus related to the decisions and behaviours of individuals.
5. Interactive uncertainty. Uncertainty may be the result of interactions between individuals or between individuals and institutions or companies. This form of uncertainty can usually be formalised by means of (epistemic) game theory, even if it cannot be quantified.
6. Value uncertainty. Philosophers and economists have recently begun discussing the normative component of uncertainty, which goes beyond its factual forms. They have thus introduced the notions of moral uncertainty and normative uncertainty (Lockhart 2000; MacAskill et al. 2020). The latter is a much broader concept than the former. Moral uncertainty is intended as uncertainty about what we morally ought to do (MacAskill et al. 2020: 2). Normative uncertainty involves norms in the legal sense, but it 'also applies to uncertainty about which theory of rational choice is correct and uncertainty about which theory of epistemology is correct'

[4] In the context of modeling, parametric and model uncertainties are usually considered to be epistemic forms of uncertainty, while Hansson (2022b) considers them to be factual forms of uncertainty.

(MacAskill et al. 2020: 2–3). It focuses on the value-based dimensions of conditions of inexactness and unpredictability (Taebi et al. 2020). Thus, normative uncertainty involves valuative considerations in those aspects of decision-making related to epistemology, ethics, law and politics.
7. Structural uncertainty. The true structures, limitations and impacts of complex decisions are almost always unknown. This uncertainty may be caused by a number of factors: (a) the delimitation of the issue covered by the decision may not be fixed or known; (b) the scope of the decision may be unclear; (c) it may be unclear who is going to make the decision; (d) the timing of the decision may be uncertain; and (e) the consequences of the decision may be difficult to conceive and evaluate.
8. Linguistic uncertainty (ambiguity). This uncertainty is due to linguistic ambiguity and is mainly related to the semantics of the terms involved in decision-making.

1.2.4 Types of Uncertainty and Climate Change in Cities and Regions

In this subsection, we provide specific examples connecting contemporary cities and regions with different uncertainties. In doing so, we focus on one of the major themes with which the notion of uncertainty is often associated in these contexts. Our intention is to show how all the different types of uncertainty listed above take shape around the general phenomenon of climate change and their implications for cities and regions.

Climate change is a fact based on scientific evidence reported in more than 14 000 scientific publications (Masson-Delmotte et al. 2021). Nevertheless, according to some scholars, uncertainty remains intrinsic to climate change, not per se, but due to: (1) the magnitude of the various inputs that contribute to the climate regime (Heal and Kristrom 2002); and (2) its several implications, mainly socioeconomic (Heal and Millner 2014).

Especially 'in the early days of climate science, uncertainty was often seen as challenging the authority of science itself, causing uneasiness among scientists' (Mehta et al. 2019: 1529). It was at the beginning of the twenty-first century that the Intergovernmental Panel on Climate Change (IPCC) recognised five stages of uncertainty: (1) emission scenarios; (2) responses of the carbon cycle to emissions; (3) sensitivity of the climate to changes in the carbon cycle; (4) regional implications of a global climate scenario; and (5) possible impacts on human societies (Heal and Kristrom 2002). According to Heal and Kristrom (2002), these five stages of uncertainty can be aggregated into three main types of uncertainty: scientific uncertainty, impact uncertainty and policy uncertainty. From an alternative perspective, according to the PRIMAVERA project funded by the European Commission in 2020 (PRIMAVERA 2020), in climate sciences we can distinguish three types of uncertainty: natural variability, scenario uncertainty and model uncertainty. This is a partial classification limited to climate projections, but it is useful to recall it along with the other different classifications to place all of them in relation to the types of uncertainty theorised by Hansson (2022b). For instance, according to Hansson's texonomy, natural variability and model uncertainty are special forms of factual uncertainty, and this is not very common because model uncertainty is usually considered something epistemic, whereas scenario uncertainty seems to be mainly related to possibilistic uncertainty. However, it is important to distinguish: (1) uncertainty about which model best represents the phenomenon or which model is more reliable, which leads to empirical uncertainty; and (2) uncertainty about which model is more compatible with the evidence, especially if you have scarce data at your disposal. This type of uncertainty would count as metadoxical uncertainty. Let us now reconsider Hansson's taxonomy with reference to the uncertainties related to climate change:

1. Factual uncertainty is mainly related to natural variability and objective facts. It is linked to what has been happening in cities and regions due to climate change, including all the aspects related to the availability of data and statistics, with an emphasis on differences between countries, regions and cities. In this case, from an empirical and analytical point of view, science plays a decisive role. A possible example of the factual type of uncertainty is the sea-level rise phenomenon, which is affected by model uncertainty.[5] This phenomenon may impact differently on coastal cities and settlements due to local specificities that cannot be completely and equally known, such as coastal geomorphology, sea bathymetry, and urban morphology. Regardless of model uncertainty, factual uncertainty is closely linked to the impossibility of knowing every geographical situation with the same detail and quality of information.
2. Possibilistic uncertainty is mainly based on scientific and technological reasons and is connected to everything we might discover but is still unknown. Disruptive technologies may improve, for example, the way to mitigate anthropogenic emissions of greenhouse gases as well as the way infrastructures and built environments can adapt to global warming and unprecedented climate events. In this case, science especially plays a decisive role, not just from the empirical-analytical point of view but also from the point of view of its twofold innovative potential, that is: (a) to improve and extend the existing knowledge; and (b) to propel technology in new directions (Park et al. 2023).

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[5] It is worth noting that the future scenarios assessed by the IPCC have different levels of confidence according to the so-called Representative Concentration Pathways (RCPs).

3. Metadoxastic uncertainty involves, for instance, the cogency and reliability of data and projections regarding global warming. Such uncertainty is caused by doubt about whether the model used in an assessment process is correct (Gardoni and Murphy 2014). The effect of this form of uncertainty strongly affects urban planning and policies, since urban planners and policymakers rely on a chosen set of quantitative assumptions and statistical projections among those provided by different subjects and with different levels of confidence and accuracy. To reduce the metadoxastic uncertainty in the field of climate change studies, intermodel and interscenario comparisons have been developed in the form of model intercomparison projects (MIPs) aimed at implementing a common study protocol (Tavoni et al. 2015; Wang and Teng 2022).
4. Agential uncertainty mostly relates to the personal and to implications of global warming and is connected to how likely it is, for example, that individuals will consider cities less habitable or safe than other geographic and settlement contexts, while also anticipating new types of housing, jobs and transportation forms. In this case, the attention is placed on purely individual choices that are independent of both endodoxastic and metadoxastic uncertainties (see Hansson 2006).
5. Interactive uncertainty is another form of uncertainty sensitive to social and political implications. It influences negatively or positively the way, for instance, in which building, industrial and transport constraints will be accepted, transgressed or possibly subjected to forms of social imitation. This type of uncertainty also encompasses the risks of organised forms of protest by groups of people against decision-makers, political leaders and public institutions, as well as the formation and contribution of new international climate alliances and movements, or new green local communities.
6. Value uncertainty is mainly linked to the principles placed at the basis of ethical and political theories, national and international political agendas, and constitutional frameworks. By way of example, we may ask whether and to what extent climate change will guide urban agendas and policies, or whether other events, such as pandemics and a new war, will contribute to shifting them towards new, not converging objectives (Taebi et al. 2020).
7. Structural uncertainty. A crucial component of uncertainty related to climate change also pertains to the role of national and international bodies and networks involved in the forecasting, monitoring and policy implementation processes. Particularly, structural uncertainty is related to questions about where the governance of climate change should take place and who should conduct and be responsible for the governance of climate change (Bulkeley and Newell 2023: 11). While the main objective of the

decisions to be taken seems to be almost clear (the reduction of greenhouse gas emissions), the spatial and temporal delimitation of the scope is not completely fixed, and the decision responsibility is consequently fragmented and unclear. In recent years, many governments have wondered about which governance structure is suitable for implementing climate transition and climate neutrality. New national climate laws, for example, have been adopted in the European Union to provide a legal framework for decarbonisation and greenhouse gas reduction (CAN Europe 2022). These kinds of initiatives confirm the importance of 'structural factors in shaping the international climate negotiations and policy outcomes' (Bulkeley and Newell 2023: 11).

8. Linguistic uncertainty. This kind of uncertainty has to do with ambiguity. It is therefore necessary to remember here how much, even only at the media level, the perception of climate change can derive from purely linguistic choices and constructs. Let us think, for example, of terminologies that emphasise the exceptionality, unpredictability or anomaly of some climatic events that are instead the manifestation of a phenomenon that is anything but exceptional, unpredictable or anomalous, such as climate change. This is the case of 'anomalous waves', 'water bombs' and 'anomalous heat waves'.

Even though the interplay between different types of uncertainty has a clear impact on decision-making and planning strategies, it is common for uncertainty to be treated as a singular phenomenon. However, our analysis shows that uncertainty has a multifaceted nature, which means that it is possible to identify and evaluate specific types of uncertainty. By doing so, we can create a more comprehensive and informed interpretative framework for complex sociospatial phenomena.

1.3 FRAGILITY

By 'fragility' we refer in a broad sense to the quality of an object or system (but metaphorically also of a person, a social group, a territory, and so on) to be easily 'broken' (from the Latin *frangĕre* which means 'to break') even by a minor, ordinary or nonviolent force (Chiffi and Curci 2020). 'Fragile' describes an object or system – metaphorically also a person or a social group – that for intrinsic reasons can be damaged or can suddenly break even in the face of ordinary and nonviolent stresses. Fragility may in fact increase or decrease over time, and can even appear in the absence of disruptive events or interventions due to the gradual effect of passing time, or to mere exposure to environmental agents. Strictly speaking, however, fragility is an intrinsic characteristic associated with a specific fracture modality (whether short, sudden or abrupt) that is independent from specific hazards. Exogenous stresses and shocks can increase fragility since they produce structural changes in the affected object or system, but in any case, it is not possible to speak of 'fragility to something'. Of course, it is possible to recognise new states of fragility that are the result of previous external solicitations, but fragility is not defined by what lies outside of the object, nor is it a variable depending on future hazard scenarios. From a system-oriented perspective, fragility is mainly related to a loss in functions (almost always irreversible) of the system, and when the system is 'broken' it cannot easily return to its original functionality (Ansar et al. 2017).

The concept of fragility involves some of the aforementioned types of uncertainty that result from the complexity of the object or system to which it refers. In particular, being connected with severe uncertainty, fragility is particularly sensitive to those types of uncertainty that cannot be quantified: agential, interactive and structural uncertainty. This is why one must consider the possibility of unexpected scenarios coming to the fore, which is evident not just in the case of simple objects, but even more in complex systems such as cities, territories or ecosystems. On the contrary, the notion of vulnerability is linked to a specific hazard in a clear and well-defined scenario. Indeed, being vulnerable means being vulnerable to something. When referring specifically to complex systems rather than to single objects, fragility cannot be linked deterministically to specific hazards, nor does it lend itself to probabilistic calculations. It expresses a condition of severe uncertainty related to various, and not necessarily known, factors that could cause damage and breakage.

Outside the field of material physics, the concept of fragility has been a concept with low scientific usability, although it is highly expressive and suggestive in terms of the communication of some contemporary (social and medical) facts and phenomena. Nevertheless, other scientific fields have recently begun using it as a new conceptual tool. Interestingly enough, something fragile is not necessarily vulnerable if it is protected from certain external events, or if agents are able to potentially trigger or accelerate its breaking process. In fact, when we talk about the vulnerability of an object or system, we refer to the condition of insufficiency or inadequacy of its protective means with respect to a specific potential danger. Vulnerability therefore involves those characteristics that influence the ability to anticipate, cope with and oppose a hazardous event (Wiesner 2016; Eriksson and Juhl 2012). Vulnerability regards a condition prior to a specific shock; thus, it can also refer to individuals and objects as well as to communities, systems, organisations and territories.

Averting fragility, therefore, may lead us down different paths, some of which deal with the issue of predisposition. Strictly speaking, predisposition precedes a shock without directly affecting the adaptability of a system in the subsequent phase. From a philosophical standpoint, such a predisposition (to break) can be read as a disposition (Borghini and Williams 2008). Dispositions in fact represent the ability of an object or system to trigger a certain situation (that is, its manifestation) as the result of a set of stimuli that are, in turn, linked to the dispositions of other objects involved in the shock; such other objects also have their own dispositions, and it is thanks to the complementary dispositions of the involved objects that mutual manifestations are produced. For example, a glass bottle – a fragile material *par excellence* – can be destroyed by the blow (that is, an appropriate stimulus that causes shock) of a hammer (an object with a disposition to breaking fragile objects). Dispositions are characterised by the manifestations they produce, and are thus specific to certain manifestations. As previously mentioned, the disposition to fragility has its manifestation in an abrupt and rapid rupture, and this is the reason why fragility can be seen as the disposition of an object or a system to break abruptly. However, for a disposition to possess any possible behaviour, it is not necessary for its manifestation to occur: a fragile object in fact expresses in itself the possibility and, above all, the typology of its own breaking. This also implies that a family of different stimuli can lead to the same type of shock. In the case of the glass bottle, we know that it can break in various ways, meaning that the manifestations of its disposition to being fragile are multiple and diverse: the bottle can break into two or three parts, but also shatter, crumble, and so on. Common dispositions (such as the disposition to fragility) for which there is a plurality of manifestations and appropriate stimuli (that is, proper to create shock) are called conventional dispositions. Canonical dispositions, on the other hand, are characterised by an explicit and specific set of stimulus conditions and manifestations (Choi 2008).

An example of canonical disposition is the disposition to vulnerability. Vulnerability is usually expressed with statements such as '6 per cent of buildings in this city would collapse following a storm with the wind at 160 km/h and an inclination of 44 degrees'.[6] In this case, both the stimulus condition (wind speed and inclination) and the manifestation (the collapse of 6 per cent of buildings) are well specified. It is worth noting that vulnerability can be linked to the (probabilistic) notion of the risk of a specific shock, following a precise and unambiguous description of the appropriate stimulus for determining it; fragility, instead, involves deeper forms of severe uncertainty.[7] In fact, fragility is difficult to express by means of probabilistic measures, since

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[6] Measures of vulnerability can be expressed by means of probabilities, imprecise probabilities or in a qualitative way.

[7] However, nothing prevents (probabilistic) measures from being applied to the intensity of the stimulus in a fragility-related process.

the appropriate stimulus conditions and manifestations are not always or completely (or cannot be) explicit. As we have seen, the existence of several stimuli and different possible manifestations of the shock also depends on the dispositions of the other objects able to cause the 'rupture'.

Contrary to what happens with vulnerability, the events inducing the shock do not need to be specified from time to time. The concept of fragility, in fact, involves forms of uncertainty that result from the complexity of the object or system to which it refers. This is why one must consider the possibility of unexpected scenarios coming to the fore, which is evident not just in the case of simple objects, but even more in complex systems such as cities, territories and ecosystems. In contrast, the notion of vulnerability is linked to assessing the severity of the consequences of a specific hazard in a clear and well-defined scenario.

All in all, notions such as probability, expected utility, damage and consequence assessment can be highly problematic when applied to the concept of fragility. This does not mean that probabilistic risk estimates are always useless for the analysis of fragility; yet they are clearly not the only tool available, nor do they represent the most appropriate method to follow.

1.4 ANTIFRAGILITY AND RESILIENCE

In the previous section, we outlined the connection between the notion of fragility and the notion of uncertainty. Still, fragility and risk share some properties, that is, they are not neutral terms, for they both refer to potentially negative outcomes. The notion of uncertainty, however, is used in a more neutral way (that is, from an uncertain situation may follow both positive and negative things).

Nassim Taleb (2012) introduced the concept of antifragility, which is mainly associated with the possibility of gaining positive outcomes after a shock in an uncertain context. More specifically, he pointed out that not all uncertainties can be prevented, and the idea behind antifragility is not only to survive trauma or to simply improve the performance of a given system in response to a shock, but to reinvent and evolve the system as a whole. The basic idea of the concept of antifragility is that of evaluating uncertainties at the stress level in relation to possible positive outcomes related to the future performance of a system. In this way, it is possible to integrate risk analysis, which mainly focuses on negative outcomes with an antifragile perspective that is sensitive to the positive outcomes deriving from a shock in a system. A clear explication of the concept of antifragility is owed to Terje Aven. He clarified that, unlike any form of resilience, the key contribution of the concept of antifragility is related to the possibility of coping with the future stages of a system in which new functions can emerge. If the system is not resilient, it is not able to sustain its functions in the presence of a specific stress. Resilience deals with the stress dimension but does not see this in relation to future developments of the system that extend beyond established functions (Aven 2015; Proag 2014). The main idea is that resilience is the ability of a system to absorb disturbance and reorganise while undergoing change, in order to retain its fundamental function, structure, identity and feedbacks (Walker et al. 2004).

Resilience, however, can be intended in at least two senses. According to a restricted view, resilience has the purpose of restoring the functions and the outputs of a system to a condition before the shock (the so-called bouncing-back), while according to an extended view of resilience, the previously existing functions are restored, and the system can even produce better outcomes with respect to the pre-shock condition (the so-called bouncing-forward). In recent years, we have seen how much the concept of antifragility struggles to be disentangled from resilience.[8] Antifragility has been in fact considered by some literature as 'extended resilience' (Blečić and Cecchini 2020), which is sometimes also termed (with some small conceptual variations) 'hard resilience' (Proag 2014), 'transformative resilience' (Dahlberg 2015), 'aggressive resilience' (Carey 2020) and 'global resilience' (Thorén 2014), among others.[9] According to Blečić and Cecchini's interpretation, antifragility would be more specifically a limit case of 'extended resilience', which goes beyond the perspective of a mere return to the state prior to the shock. However, it is worth noting that extended resilience occurs without any fundamental change in the structure and function of the system. Only antifragility has the possibility to deal with the emerging functions of a system after a shock to gain positive outcomes, also by virtue of these new functions, and these new functions may be due to structural redundancies of the system. The assessment and evaluation of possible emerging functions in a system after a shock are crucial elements in differentiating antifragility from extended resilience. In this way, a system may become as adaptive, responsive and flexible as possible in the future (Derbyshire and Wright 2014). As suggested

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[8] It seems that this extended form of resilience was not considered by Taleb. He pointed out that 'the ... resilient is neither harmed nor helped by volatility and disorder, while the antifragile benefits from them' (Taleb 2012: 17). Still, we think that antifragility can be differentiated by extended resilience.

[9] Resilience was introduced as a descriptive ecological term by Holling (1973). He also proposed a classical distinction of two types of resilience. He distinguished between 'engineering resilience' and 'ecological resilience', observing that 'the first definition, and the more traditional, concentrates on stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property', while 'the second definition emphasizes conditions far from any equilibrium steady state, where instabilities can flip a system into another regime of behavior – that is, to another stability domain' (Holling 1996: 33).

by Aven (2015: 482), 'the antifragility concept emphasizes the importance of not being satisfied with performance compliance at specific points in time. What is coming next needs always to be highlighted'. And notably, in a system that is extensively resilient, future exposure to uncertainty should still be minimised, while an antifragile system would seek to increase future exposure to uncertainty (Munoz et al. 2022). Antifragile systems may require stressors to stimulate positive adaptation. This means that in the case of new exposure to uncertainty, the antifragile system, by virtue of its capacity to promote new functions, can keep gaining from uncertainty, while a resilience system cannot introduce new functions and benefit from exposure to new uncertainty. Finally, resilience may be more localised. A specific part or component of a system can be resilient, while antifragility always refers to the whole system.

These are the reasons to avoid the collapse of antifragility into resilience. Therefore, the distinction between these two concepts is clear from the dynamic perspective of systems facing recurrent disturbances and disruptions: if one focuses on a single shock, it is more likely that people confuse resilience and antifragility.

1.5 CONCLUSION

Concepts such as risk, uncertainty, fragility, vulnerability and resilience suffer from severe semantic variability, which may deeply impact upon the ways in which we conceptualise, organise and regulate ecological and social systems. This is particularly true in the context of urban and regional research, in which space and society interact in extremely complex systems. In this chapter, we have critically discussed those probabilistic risks that can be measured, and forms of (severe) uncertainty that can resist any form of quantification or even formalisation. More specifically, we have discussed different types of uncertainty related to climate change, since this phenomenon is a challenge for all contemporary cities and regions and involves a great variety of uncertainties.

The notion of risk is a normative and evaluative notion with a negative connotation, while the notion of uncertainty is a much more neutral concept with possible negative or positive consequences. Given this twofold characterisation of uncertainty, we have analysed the concept of fragility, which is related to the negative consequences of uncertainty related to a stress of the system, and the opposite notion of antifragility, related to the positive consequence subsequent to the stress. Both notions, of fragility and antifragility, consider the functionality of the system to be a key factor. In the context of a fragile system, some functions are (even irreversibly) lost and cannot be restored, while in the context of antifragile systems, new functions may emerge after stressing the system. We have explored the distinction between fragility as one concept related to the constellation of concepts connected to uncertainty and the notion of vulnerability, which is much more sensitive to issues in risk analysis. Furthermore, two senses of resilience have been isolated: a restricted sense of resilience in which a system is capable of restoring its original functions after a shock, and an extended sense of resilience in which the original functions of the system are restored and their effects have overall improved the system compared to the pre-shock situation. Extended resilience has been collapsed by some authors into the notion of antifragility by virtue of its apparent similarities. However, only antifragility can increase the functions of a system after a shock.

The main reason for applying the concepts of fragility and antifragility to urban and regional problems is to be found in the necessity of dealing with different types of uncertainty related to wicked problems. However, another reason is the unsustainable increase in inequalities between people, social groups and territories. Social inequalities do not only always assume a spatial dimension, but are one of the main causes of the fragility of contemporary territories. In light of this, when considering the forms of fragilities that affect territories, we can recognise a transition between two different paradigms. In fact, in recent decades, the focus on sociospatial gaps appears to have moved away from the developmental paradigm that interpreted gaps as a 'lag in development'. The focus seems now to have shifted towards the 'distributive and environmental justice' that is present even in the most developed and economically advanced territories; which should, on the one hand, promote a fair distribution of risks and resources, and on the other hand, promote individual and collective action in the face of the uncertainty of the future. To promote the possibility of shaping the world as we desire it to be, it is indeed necessary to consider the connections between uncertainty and inequalities within cities and regions. This is a promising area for future research; indeed, it is tackled in subsequent chapters of this book.

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