Uncertainty and Planning: Cities, Technologies and Public Decision-Making

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Decision-making under uncertainty is sometimes investigated as a homogeneous problem, independently of the type of decision-maker and the level and nature of the decision itself. However, when the decision-maker is a public authority, there immediately arise problems additional to those that concern any other (private) decision-maker. This is not always clearly recognised in orthodox discussions on decisions under conditions of uncertainty. This article investigates the methodological, strategic and procedural challenges of taking public decisions in such conditions. It focuses mainly on decisions involving urban contexts, such as planning decisions regarding land use and building transformations, by trying to develop some pioneering research studies in this field.

1. Introduction: Inhomogeneous Decision Situations

Decision-making under uncertainty has captured the attention of many scholars and has been extensively discussed in the literature. The issue is often investigated as a homogeneous problem, independently of the type of decision-maker and the level and nature of the decision itself. However, when the decision-maker is a public actor (i.e., a public authority), there immediately arise problems additional to those concerning any other

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(private) decision-maker. This is not always clearly recognized in orthodox discussions of decisions taken in conditions of uncertainty.

Evidently, research on everyday decision-making in conditions of uncertainty (see e.g., Oaksford and Chater 1998; Kahneman et al. 1982; Kahneman 2011; Gigerenzen 2008) is also relevant to discussing the public actor's situation. However, the latter case has additional and very distinctive problems. Simon (1983) produced some preliminary, pioneering insights, but they have gone partly unnoticed. Simon focused not only on the particular difficulties of organizations' decision problems in general;[1] when discussing uncertainty, he also highlighted the highly distinctive problem of *social choice* under conditions of uncertainty—that is, the problem of public policy decisions taken by *public* organizations (Simon 1983, p. 84 ff.).

In what follows we discuss this issue by mainly focusing on urban planning as a prototypical example. We seek to develop the very interesting line of inquiry started in this field by Rittel and Webber (1973) and Christensen (1985), and recently carried forward by, for example, Kato and Ahern (2008), Abbott (2005), Rauws (2017), Savini (2017), Beauregard (2018), Stults and Larsen (2018), Zandvoort et al. (2018), Skrimizea et al. (2019), de Roo et al. (2020b).[2]

The background idea is that urban planning problems are almost always connected with severe uncertainty. When this is the case so-called "wicked problems" arise; that is, those problems that are difficult to state consistently and concisely in advance because their understanding and resolution are concomitant with each other (see the already-mentioned seminal work of Rittel and Webber, 1973, and, amongst the subsequent discussions of the issue, e.g., Hajer, Hoppe and Jennings 1993; Koppenjan and Klijn 2004; Balint et al. 2011). The main idea is that wicked problems always come in a complex form; they are often ill-defined a priori, and they may lack a well-defined structure. Cities are complex and fundamentally uncertain objects, and urban planning must therefore constantly deal with wicked problems.

1. "Simon identified decision-making in conditions of uncertainty and interdependence as the basis on which administrative theory could be rebuilt and thereby created the premise for a new vision of human activities within organizations" (Egidi and Marengo 2004, p. 336). As is well known, he pointed out that the selection of rational goals is constrained by the contingent fact that organizations may have too few resources to deal with all the information and alternatives required to formulate and implement optimal goals. This fact entails that rational goal-setting has to be understood in terms of the organizational context in which the goals are established. For these goals to be achieved by collective decisions, they need to be coherent with the paradigm of bounded rationality in which cognitive and empirical resources are scarce.

2. As Christensen (1985, p. 71) wrote: "Planners should address uncertainty, not ignore it."

The present article—by also trying to resume certain undervalued insights anticipated by Simon—investigates the methodological, strategic, and procedural challenges for public agencies taking planning decisions under conditions of uncertainty. It focuses mainly on decisions involving urban contexts (e.g., planning decisions regarding land use and building transformations) in which there is uncertainty associated with the urban behavior of public decision-makers and citizens.

Section 2 highlights the distinguishing features of public decisions and the two ways in which uncertainty may occur in the decision framework. Section 3 discusses the different ways in which a public actor may address those problems involving uncertainty. Section 4 focuses on technology. Section 5 concludes by summarizing the main achievements and considering open questions.

2. Planning Problems

We distinguish among conditions of certainty, risk, and (severe) uncertainty:[3]

i. in a situation of *certainty*, possible events are listable; the consequences of each choice are known to the decision-maker; and choices indubitably lead to specific outcomes.
ii. in a situation of *risk*, possible events are still listable, and the decision-maker is able to assign (meaningful) probabilistic values to them.
iii. in a situation of severe *uncertainty*, the decision-maker is unable to assign well definable or computable probabilities and may even be ignorant about what states of affairs are possible.[4] (In social-spatial systems, one component of this kind of severe uncertainty is so-called "interactive uncertainty"; that is, a situation in which the effects of one agent's actions and decisions also depend on interaction with other agents: Hansson 2022).[5]

3. Other typologies of decision situations have been proposed in the literature (as regards planning and organizational research, to be cited are some classic works presenting taxonomical approaches and conceptual models for dealing with uncertainty: Emery and Trist 1965; McWhinney 1968; Alexander 1972, 1975; Christensen 1985; Thompson 2003). We focus here on the taxonomy that we believe is especially important for our overall argument (as regards the specific way in which we employ certain concepts—comprising that of risk, which is sometimes used in a different sense—see the following footnotes).

4. On this idea of severe (fundamental, radical, deep, etc.) uncertainty (as opposed to certainty and risk), see, for example, Knight (1921); Shackle (1961); O'Driscoll and Rizzo (1985); Langlois (1986a, 2007); Langlois and Everett (1992); Wubben (1995); Harper (1996); Hansson (1996); Dequech (2000, 2001, 2006); Chiffi and Pietarinen (2017); Moroni and Chiffi (2021).

5. Interactive uncertainty may be handled and formalized by means of (epistemic) game theory (Chiffi and Pietarinen 2017).

Most decisions relevant to urban contexts do not take place in certainty or risk conditions, but instead in ones of severe uncertainty (Abbott 2005; Rauws 2017; Zandvoort et al. 2018).[6]

Regarding decision-making in conditions of uncertainty, it may, however, be useful to distinguish two main situations when dealing with cities. First, local public decision-makers may be in decision-making circumstances involving uncertainty. Second, all private actors (e.g., landowners, developers, architects, shopkeepers) acting and living in the city may have to take decisions under conditions of uncertainty as well.[7] However, the condition of public decision-makers is doubly complicated, since uncertainty arises twice in their case.[8]

First, public decision-makers must cope with the uncertainty of the decision itself, which mainly depends on the fact that urban systems are complex, dynamic, evolutive and, to a large extent, unpredictable (Batty 2005; Portugali et al. 2012; de Roo et al. 2012). The decision therefore cannot be grounded on predictions of the future—for instance, predictions regarding the behaviour of all urban agents—as might be possible in simple systems (Portugali 2008 and 2012).[9] As Walker and Marchau write:

> Policymaking is about the future. If we were able to predict the future accurately, preferred policies could be identified (at least in principle) by simply examining the future that would follow from the implementation of each possible policy and picking the one that produced the most favorable outcomes. However, for most systems of interest today (particularly social and economic systems), such prediction is not possible, due to their increasing complexity. (2003, p. 1)

6. It is, however, important to distinguish here between what is *unknown* in a (decision) situation of (severe) uncertainty and what is intrinsically *unknowable*. Unknowability means that a fact or proposition cannot be known even in principle or even *ex post*. Therefore, an unknowable fact or proposition must not be confused with an unknown fact or proposition. If something is simply unknown, it may become known subsequently, whereas this is not the case of unknowability. The notions of knowability and unknowability are particularly problematic also from a logical perspective, since they may generate epistemic paradoxes such as the Church-Fitch paradox of knowability (Salerno 2009).

7. On decision-making under uncertainty by developers in the real-estate market see, for example, Byrne (1984); for entrepreneurship under uncertainty, see Choi (1993); and on investment in uncertain conditions, see Dyxit and Pindyck (1994).

8. Along similar lines, Abbott (2005) distinguishes the problem of "uncertainty *for* planning" from that of "uncertainty *from* planning." Consider also the idea of "cascades of uncertainties" in van den Hoek et al. (2014).

9. As is well known, the distinction between simple systems and truly complex ones was pioneered in urban studies by Jane Jacobs (1961). For a recent critical overview of the debate on urban complexity, see de Roo et al. (2020a).

Second, public decision-makers have to take decisions (under conditions of uncertainty) to mitigate (or, at least, not increase) the uncertainty in which citizens will live and act.

3. Planning Strategies

When considering local public decisions, such as planning decisions, it is essential to distinguish between two main cases (Moroni and Chiffi 2021). First, there are situations in which public decision-makers decide on their own actions, for example if, where, when, and how to build an artefact on public land or on land acquired for that purpose, such as a public hospital or school, a new metro station or a bridge. Second, there are situations where decision-makers decide how to regulate someone else's decision on how to act, for example how to draw up building standards and planning rules that will constrain the decisions of ordinary citizens, architects, developers, etc. in relation to artefact creation or transformation.

In discussing how to cope with uncertainty, we focus here on this second, decisive task, the importance of which for society and the economy has been discussed by Ben Joseph (2005), Needham (2006) and Talen (2012). (The other task is obviously important as well, but, mainly for reasons of space, we shall not deal with it here[10]).

In this case—i.e., regulating private actions—we can clearly distinguish between the two different decision questions mentioned above (Section 2): (i) how to reduce uncertainty during institutional planning,[11] and (ii) how to reduce uncertainty for urban actors' multiple plans.[12]

As regards the latter point, observe that we are obviously not assuming here that reducing urban actors' uncertainty is the *only* aim of public measures; nevertheless, it is a crucial reason to justify, especially, the introduction of basic common rules (Langlois 1986b; North 1991 and 1995; Streit 1997; Kasper and Streit 1998; Loasby 1999; Engel 2005).[13] As North (1995, p. 15, 24) writes, institutions—i.e., "the constraints that human beings impose on human interaction"—exist "to reduce uncertainty in human interaction

10. On the (not dealt with here) other case of public planning intervention (i.e., providing public infrastructure), interesting insights on how to deal with uncertainty can be found, for instance, in Olsson (2006), Kwakkel et al. (2012), Giezen (2013), Salet et al. (2013), and Givoni and Perl (2020).

11. "Regulators typically decide under conditions that are largely uncertain" (Engel 2005, p. 162).

12. We can obviously assume that everyone plans, but it is important to maintain the crucial distinction between institutional planning by public authorities and everyday planning by ordinary citizens. On this, see Haken and Portugali (2014).

13. On how inadequate institutional frameworks and actions can, unwantedly and by contrast, increase uncertainty see, for example, Bylund and McCaffrey (2017).

precisely because of the limited information we possess to evaluate the consequences of the actions of others and the limits of the models we possess to explain the world around us." The same point is stressed by Loasby (1999, p. 46): "institutions are a response to uncertainty. They are patterns [...] which guide individual actions, even when these actions are quite unconnected with any other person. They economize on the scarce resource of cognition, by providing us with ready-made anchors of sense."

3.1. Reducing Uncertainty While Planning: Adopting an Evolutionary Approach to Rules and Preferring Negative Rules

The first question therefore relates to how a public actor deals with those forms of uncertainty directly related to its own decisions; that is: how proper planning and building rules can be devised amid of severe uncertainty. Beyond the widely discussed use of novel methods and techniques that are undoubtedly helpful in this regard,[14] at least two more substantial strategies seem possible: (i) to embrace an evolutionary perspective on rules, and (ii) to prefer negative rules.

First, decision-makers should dismiss a constructivist approach,[15] which is quite common and still persistent in traditional forms of planning, and instead embrace an evolutionary perspective (see e.g., Vanberg 2001 and, with specific reference to planning, Moroni 2010b). According to an evolutionary perspective, the point is not to try to invent and create novel basic rules continuously but rather to recognize and improve those basic rules that have successfully evolved over long periods of time and have shown their capacity to foster beneficial socio-spatial arrangements (with regard to urban rules see in particular Akbar 1988 and Hakim 2014). Although the existence of certain basic social norms cannot be justified in the way that constructivism requires, the long processes behind their formation and development can be reconstructed by using an evolutionary

14. An example here is scenario building. On this, and with specific reference to planning, see, for example, Xiang and Clarke (2003); Derbyshire and Wright (2014); Chakraborty and McMillan (2015); Zapata and Kaza (2015).

15. The term *constructivism* is used here in the Hayekian sense. According to Hayek (1982, I: pp. 8–9), constructivism maintains that human institutions (i.e., basic rules of conduct) (i) "will serve human purposes only if they have been deliberately designed for these purposes," often also that (ii) "the fact that an institution exists is evidence of its having been created for a purpose," and always that (iii) "we should so re-design society and its institutions that all our actions will be wholly guided by known purposes." See also Hayek (1952, p. 83): "From the belief that nothing which has not been consciously designed can be useful or even essential to the achievement of human purposes, it is an easy transition to the belief that since all institutions have been made by man, we must have complete power to refashion them in any way we desire." On constructivism, see also Smith (2008).

approach that enables us to understand to some extent *how* and *why* they function (Hayek 1988, p. 69). As Ostrom observes, individuals and groups "across time and space have already devised an incredible richness in the rules they use. We need to learn more about this heritage to be better facilitators of better institutional designs—in contrast to presuming we are experts who can devise the optimal design to solve a complex problem" (2006, p. 119). Clearly, not every rule that has emerged through evolutionary processes over time is always and in itself desirable (Alexander 2011), but there are some that we can recognize *a posteriori* as such and that we can therefore formally guarantee and defend.[16]

Second, decision-makers should in general prefer rules that are mainly negative; that is, proscribing certain negative externalities rather than prescribing specific actions (as specifically regards urban planning, see on this Moroni 2010a; Moroni and Cozzolino 2019; Alfasi 2018; Cozzolino 2020). Note that formulating positive obligations (e.g., houses must be built in compliance with certain technical specifications) generally requires more knowledge than is needed to merely set negative rules (e.g., avoid nuisance X). Kasper and Streit (1998, p. 97) observe that the decision-maker who wants to prescribe actors' behavior should be aware of those actors' skills, the means at their disposal, and the possible effects of the behaviors imposed. By contrast, the public decision-maker that only wants to rule out certain types of behavior, as in the case of prohibitions, merely needs to know that certain actions are unwelcome without trying to list all the different ways in which urban actors may respond to its decision; in this case, decisions regarding the specific goals and details of individual behaviors and the assessment of their consequences are left to the urban actors (Kasper and Streit 1998, p. 97).[17]

Consider the following example of a very specific prescriptive rule (taken from an Italian local building code adopted in 2014 by a municipality in the Lombardy Region):

> To reduce the consumption of drinking water [...] when the surface area of a building's gardens or courtyards exceed 200 square meters,

16. Observe that our argument is not a (substantive) normative argument in favor of specific rules, but an epistemological and praxeological caveat on what kinds of rules should primarily be carefully considered.

17. The decision-maker may also evaluate whether positive obligations may promote planning goals that are *achievement-inducing* by all the actors involved in the decision process. This kind of evaluation may be based on rational criteria of precision, evaluability, approachability, and motivity for the evaluation of planning goals (Edvardsson and Hansson 2005). However, the achievement-inducing capacity of goals of this kind may be difficult to control and evaluate when referring to highly uncertain and complex scenarios.

> it is obligatory to provide for the collection of rainwater from the said building's roof, for the purpose of watering the lawns, flower beds and/or washing the courtyards and pathways. To this end, the roofs must be equipped with a system of rainwater collectors and conduits, leading to reservoirs that store water for recycling. [...] Hence, the size of the cisterns must be large enough to store the year's rainfall in order to provide sufficient water for irrigation and cleaning (min. volume) or for other envisaged uses (such as supplying water for WCs, laundry rooms, air-conditioning units, etc.). In particular, the overall capacity of the rainwater system [...] must not be less than 35 litres per square metre of residential roof (even partial).

This rule intends to prescribe specific behavior and requires specific actions and a certain amount of detailed knowledge. A more general proscriptive rule with the same general goal (i.e., reducing drinking water waste) might run as follows: "It is prohibited to use drinking water for the purpose of irrigation, or for cleaning courtyards and pathways." In this second case, the decision-maker does not need specific knowledge of technology; what technologies to be adopted are left to individuals' free choice (and the technological innovation potential) but are still within a clear predefined framework.

3.2. Reducing Uncertainty for Urban Actors: Preferring Simple and Stable Rules and Favoring Social Calculation Systems

Considering the reduction of citizens' uncertainty that the public decision-maker may deliver when providing public rules, the following three main strategies seem promising: (i) prefer simple rules, (ii) enact stable rules, and (iii) provide rules which favor the emergence and appropriate functioning of "social calculation systems."

First, decision-makers should enact simple rules (see in general Epstein 1995; Ratnapala 1997; Zywicki 1998; and, with specific reference to urban planning, Webster and Lai 2003; Moroni and Cozzolino 2019). Complex rules, which are peculiar to traditional and current land use plans and building codes, are undesirable because they overburden human cognition and inflict unnecessarily high compliance costs (Epstein 1995;

18. Consider this example of a very complex planning rule taken from an Italian land use plan (adopted in 2011 by a municipality in the Lombardy region): "Should it prove unfeasible to create the private parking spaces and/or car parks cited in the previous clause, and in exception to indications at the letters 'b', 'c', and 'd' above, in the areas accorded to the buildings in question, owing to lack of spaces, features of the terrain, inaccessibility of public spaces, it may be acceptable to utilize—either wholly or in part—areas outside the zone of the buildings, provided that the use of the land therein does not clash with the regional transport regulations in force, and that the said areas are equipped with adequate access routes and are located in a suitable position for the said purpose and contained within

Kasper and Streit 1998; Katz and Bommarito 2014).[18] Moreover, in certain cases complex, inextricable rules defer and transfer political decision-making from the political arena to the court of law, increasing citizens' uncertainty (Liebwald 2015). By contrast, simple rules reduce the costs that private actors (e.g., landowners, developers, shopkeepers) must bear to comply with them, such as the costs of understanding which specific rule effectively applies to their circumstances, finding out what they must actually do to comply with it perfectly, and demonstrating this compliance to the public agencies. In conclusion, simple rules reduce the uncertainty that urban actors have to deal with.

In particular, public authorities have to provide both *simple individual rules* and *simple rule systems*. Simple rules have three main features: (i) they are understandable and determinate (i.e., written in clear and plain language); (ii) response to them is binary (i.e., one either complies or does not comply);[19] and (iii) they are general in nature (i.e., they refer to a few general situations or actions and not to many specific ones).[20] Simple rule systems exhibit three features: (i) simple rules as components; (ii) low density (i.e., they comprise a low number of rules or a low rule density); and (iii) low differentiation (i.e., not too many agencies contribute to introducing rules in the same sector) (Moroni et al. 2020).

Second, public authorities should make stable rules. By "stable rules" we obviously do not mean perpetually fixed rules, but instead rules which remain a reliable framework for a sufficiently extended period of time. As Loasby (1999, p. 124) stresses, "frameworks may change too, but they must change more slowly—or they cease to act as framework." Rules such as planning rules and building standards enable individuals (e.g., urban actors) to have dependable assumptions and expectations in general over long periods of time with regard to the behavior of others (e.g., other landowners or householders) and in relation to the actions of the public authority itself (e.g., the local government). A certain degree of stability

a radius of 100 metres, which can be expanded only in case of effective unavailability of areas, up to a maximum radius of 300 metres, and that they are assigned as parking areas for the entire duration of the building which they serve through signed contracts registered with the public authorities at the expense of those holding the deeds."

19. In this case, the answer to a single question (of fact) determines the (legal) outcome (Epstein 1995, p. 25).

20. As regards the first two points (plain language and binary rules), it must be stressed that assuming that simpler rules can be created does not imply acceptance of the idea that *in claris non fit interpretatio*: each and every rule always requires some kind of interpretation. The idea is that simple rules remove *unnecessary* complexity and obscurity. As Kimble (1994, p. 78) writes, "we are told that litigation will occur with or without legalese because the essence of law is in the legal interpretation of meaning. To say that, though, is to ignore the unnecessary litigation that poor legal drafting produces."

is therefore crucial if urban actors are to be able to take law as an ingredient of their life plans, doing so both in their short-term and long-term decisions and actions (Leoni 1961). As Jakee and Spong (2003, pp. 131–32) observe, "the expectations that others will also follow established rules and conventions allow the individual to rely on much broader social outcomes, such as generalized social stability. In socially stable environments, individuals are likely to have greater confidence that their personal safety and property are secure, which allows them to devote more energies and resources to productive outlets." In short, to quote Epstein (1995, p. xii), "permanence and stability are the cardinal virtues of the legal rules that make private innovation and public progress possible."

It is effectively burdensome to know, abide by, and respect constantly revised rules. If public rules are constantly changed, the decisive information they provide becomes negligible and useless (Brennan and Buchanan 2000). In short, unstable rules add uncertainty to individual behaviors. In relation to frequent variances/modifications of local plans, the 1995 local land use plan of Turin (Italy), for instance, had more than two hundred of them. To consider another example: in the past decade, many forms of incentives have been introduced in Italy at the national level for the refurbishment and renovation of old buildings: for instance, incentives for the restoration of buildings, energy efficient improvements, buying new furniture and large domestic electrical appliances, anti-seismic systems, and renovating façades. These measures have had some positive effects, but they have been introduced in too fragmented a manner and have been subject to constant reassessment: many incentives have been temporary and subject to extension; extension has come with the revision of certain crucial elements, such as the percentage of the tax break, for instance, or the maximum expenses to which the incentives can be applied.

By contrast, stable rules improve the reliability of urban actors' decisions, with the consequence of facilitating interaction among them.[21] When considering basic rules (e.g., rules regarding urban settlements), we are not dealing with a *tabula rasa* but rather with a long-standing, established framework. This suggests that reform of basic rules must be gradual.

The stability of urban rules could be enabled—apart from a change in the currently widespread constructivist mentality—through institutional mechanisms, for instance, by requiring that local building and land-use rules are revised and changed only through some sort of supermajority,

21. Observe that the only rules that can effectively remain stable are those that deal with general aspects of the urban reality and do not seek to control its details. In short, it is owing to the tendency to apply overly detailed and specific regulations that we have failed to ensure stability of planning rules and building codes.

while a simple majority could remain sufficient for the other local government tasks (i.e., providing public services and infrastructure) (Moroni 2015). This is only an example intended to suggest that some institutional mechanisms are also needed to deal with the issue of stability; other mechanisms could obviously be imagined (Leoni 1961; Hayek 1982; Brennan and Buchanan 2000).

Simple and stable planning and building rules serve to reduce, but obviously not to eliminate, uncertainty for urban actors. Rules of this kind narrow the range of possible behaviours to some typical and general classes. Such rules can guarantee soft predictability at least, but certainly not hard predictability (i.e., full predictability and detailed predictability) (Engel 2005). They provide a form of pattern coordination, not a coordination of detail among urban actors (O'Driscoll and Rizzo 1985). Consequently, people's behavior becomes predictable solely and properly for some standard situations. For instance, I cannot know in advance precisely what technologies will be adopted in the building under construction on lot X that lies alongside my own lot and building (e.g., what type of energy production devices will be installed). I can only know that on lot X, irrespective of the type of technologies that will be chosen, certain externalities must be excluded, such as certain specific kinds of pollution, noise levels, or any unsafe situation.

Moreover, simple and stable planning and building rules may contribute to increasing citizens' leeway in respecting public rules and increasing attempts to achieve public goals without excessively renouncing to their individual values and decisions. Thus, public intervention understood in this sense may favor an ordered coexistence of different individuals' and groups' goals in the presence of urban complexity and uncertainty.

Third, public authorities must provide rules that help the appropriate functioning of what we may call "social calculation systems"; for instance, the market system. Calculation systems should be understood here in a minimal sense as those societal mechanisms that may assist human beings—with limited computational capabilities—to make decisions under conditions of severe uncertainty.[22]

As Hayek (1948) pioneeringly stated, the market is primarily a calculation system of this kind. It is a method to provide information through the price system so that actors can assess the comparative advantages of possible different uses of resources (Hayek 1988, p. 77). The price system enables individuals to exchange abstract information even when they are

22. On the connection between cognitive limitations and abductive and economic forms of reasoning, see Woods (2012); Chiffi and Pietarinen (2019, 2020).

remote from one another. In this sense, the market system provides individuals with a sort of telecommunication system. It thus circumvents their individual ignorance (Hayek 1988, p. 81). In short, "prices emerge in an open-ended context in which entrepreneurs must grapple with true Knightian uncertainty" (Kirzner 1988, p. 14).

This argument was developed by Simon specifically to suggest ways to cope with decisional uncertainty. As Simon (1983, p. 88) pointed out:

> Over a wide range of matters, we can use markets and pricing to limit the amount of information each person must have about the decisions he is going to make. When I go to the local supermarket, I can decide what to buy and what I am going to eat without knowing very much about how Wheaties and oatmeal are made or what the manufacturer's problems are [...]. For this reason, markets and prices have proved to be extremely powerful mechanisms in modern societies for helping each of us to make decisions without having to learn a lot of detail about other people who may be involved.

The market system can therefore be considered a mechanism that enables actors with an insurmountable bounded rationality—i.e., having limited information and computational capacity—to operate in conditions of severe uncertainty (Simon 1983, p. 89). Simon observes that this is an argument in favor of markets quite different from, and more powerful than, the optimization argument found in orthodox economics books (Simon 1983, p. 88). Even without assuming perfect rationality of economic actors and perfect competition, market systems provide a way to reduce how much it is necessary to know to take action (Simon 1983, p. 89). In our opinion, these kinds of "institutionalist" considerations in Simon's works have gone largely unnoticed, even though they are of crucial importance.[23]

In summary, thanks to a decentralized market mechanism, which can be defined as a form of "division of knowledge," echoing the expression "division of labor," people can make use of more knowledge than they individually possess. We may accordingly claim that knowledge grows by division (Loasby 1999; Butos and McQuade 2002). According to this view, the market system is therefore a response to individual cognitive and information limitations (Aimar 2009).[24]

23. We are not assuming here that there is a complete overlap between the approaches of Hayek and Simon; we are simply highlighting certain interesting similarities between them.

24. Clearly, from the point of view of an omniscient observer, the market generates some misallocations. However, for non-omniscient observers, as we all are, it make no sense to label inefficient (in standard allocative terms) a mechanism, the inefficiency of which no one could discover in advance, independently of the achievements of the market itself. In short, "one cannot criticize the market according to criteria that ignore the basic problems

Nonetheless, *common rules* are obviously necessary for the existence of the market itself. Note also that we are manifestly not asserting that the market is the only social mechanism that can help in circumventing individual bounded rationality. It is simply an example of how certain collective mechanisms can be reinterpreted (and appropriately enabled) as instruments to cope with uncertainty problems. Moreover, we are obviously not assuming that there are no negative aspects to market mechanisms; we need rules to also exclude, for example, nuisances from their functioning.

4. Unplannable Technology

The relationship between technology and levels of decision-making in urban situations is quite complex. From a semantic—or, better, pragmatic—perspective, Floridi has proposed the following question-answer characterization of uncertainty: "If one has the question but the incorrect answer, one is insipient. If one has neither, one is ignorant. And if one has only the question but not the answer, then one is uncertain. Uncertainty is what a correct answer to a relevant question erases" (Floridi 2015, p. 1). In this sense, being uncertain is not always a completely negative condition, since it is better to know at least the relevant questions at stake, rather than not knowing both the questions and their possible solutions. The latter case, as we have seen, would be equivalent, using our terminology, to a condition of severe uncertainty or even ignorance involving "wicked problems," which are quite common in planning practice and are often about the selection of different policies and technologies.

Inspired by Floridi's approach, we propose a taxonomy that may yield further insights regarding public decisions and uncertainty in relation to technological issues, coherently with the strategies that we have proposed in order to mitigate or benefit from uncertainty. Our taxonomy shows relevant and idealized cases that relate public planning decisions and private individual choices to the technology to use:

1) First, if the public decision-maker does not promote general, stable and mainly negative rules that express clear and simple aims, such as avoiding certain specific, well-defined negative externalities, then individuals are very likely to be uncertain about the proper selection and adoption of any specific technology that may comply with public aims; this is a kind of unreduced double uncertainty affecting both public decision-makers and individuals.

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the market is designed to solve—heterogeneity and lack of omniscience" (Vaughn 1994, p. 60; compare with Ebeling, 2003; with reference to planning, see Pasour 1997).

By contrast, if the public decision-maker supports general, stable and mainly negative rules expressing simple aims, there are three remaining cases in which the potential adoption of a technology by private actors may occur in different forms, namely:

2) The private actor does not have at his/her disposal any specific technology and/or is unable to identify any technology to satisfy his/her objectives; in this case, private actors are ignorant regarding the use of technology.
3) The private actor adopts a technology that is not coherent with the public decision-maker's aims; in this case, the actor is not uncertain or ignorant but insipient regarding the choice of the technology.
4) The private actor is able to use or even invent a suitable technology to satisfy the public decision-maker's aims; this is a situation in which there is neither ignorance nor insipience, and uncertainty has been properly handled.

Broadly speaking, the specific technology choice is ultimately made by private actors that may directly change the world, while public decision-makers state the rules to be followed to change the world. Public decision-makers must promote enduring legal, social and economic conditions that may foster the innovation potential of individuals to create, develop and select new technological solutions. If so, public decision-makers should not try to "govern" (specific) technologies; rather, they should clearly state and endorse simple aims without overestimating the contingent availability of any specific technology. This strategy may leave room for the adoption of new technologies that may change the world coherently with the aims of a present and future just society and open up the prospect of technological experimentation (Van de Poel 2016). Put otherwise, normative generality and simplicity concerning planning rules and aims can provide the proper basis for urban experimentation by individuals.

5. Concluding Remarks

In this article, we have highlighted that *severe* uncertainty is unavoidable in social-spatial systems. After underscoring that there are inhomogeneous decision situations in conditions of uncertainty, we critically analyzed the possible role of public (planning) authorities in this regard.

We suggested that uncertainty can be mitigated on the side of the public decision-maker during the planning process by dismissing a constructivist approach and adopting rules that are mainly negative. Moreover, uncertainty can be reduced for urban actors by implementing simple rules and simple systems of rules, which should also be stable, and by fostering the emergence and functioning of social calculation systems. A system of

this kind should be understood as the set of social mechanisms that may assist cognitive agents in taking decisions judiciously under conditions of severe uncertainty. Market systems with their pros and cons, and even without any assumption of perfect rationality, provide an example of calculation systems with which individuals can reduce what they need to know to act in a society.

More specifically, in the context of urban planning, one observation regarding the nature of public rules is particularly relevant. Public rules, such as public planning and building rules, are helpful, not because they can directly solve social problems, but because, if they are appropriately set, they create viable and reliable expectations among a plurality of actors with irreducibly different life-plans; thus, they can reduce uncertainty in the social and economic world without necessarily hampering innovation and creativity (Moroni 2011). This suggests that institutions, as basic systems of rules, may have a crucial epistemic value that is not always clearly acknowledged.

Finally, we analyzed different scenarios concerning the creation, implementation and selection of technologies by private actors. First, we considered a scenario in which uncertainty persists for private actors due mainly to inadequate choices by public decision-makers. Then, we discussed another scenario in which the public decision-maker acts more appropriately by adopting general, stable and mainly negative rules expressing simple planning aims. In this case, we have three possibilities: (i) the individuals are ignorant of which technology to adopt, or (ii) they are insipient because they implement an incorrect technology, or (iii) they are able to manage uncertainty with a suitable technology. Clearly, case (i) can be solved (or, at least, addressed) by providing individuals with more information; case (ii) may involve a deep (and not easily solvable) disagreement between private actors and public decision-maker, whereas case (iii) may foster the technological innovation potential of individuals.

This article has been conceptual and analytical and therefore has the typical limitations of mainly theoretical inquiries. We hope that it has nevertheless been helpful in critically revisiting a crucial issue—decision-making in uncertainty situations—which also has important practical implications: for instance, in addressing specific urban problems. Further research developments could empirically explore the concrete usefulness of certain of the strategies suggested.

References

Abbott, J. 2005. "Understanding and Managing the Unknown: The Nature of Uncertainty in Planning." *Journal of Planning Education and Research* 24(3): 237–251. https://doi.org/10.1177/0739456X04267710

Akbar, J. 1988. *Crisis in the Built Environment*. Singapore: Concept Media Pte Ltd.

Alexander, E. R. 1972. "Choice in a Changing World." *Policy Sciences* 3(3): 325–337. https://doi.org/10.1007/BF01413686

Alexander, E. R. 1975. "The Limits of Uncertainty: A Note." *Theory and Decision* 6(3): 363–370. https://doi.org/10.1007/BF00136203

Alexander, E. R. 2011. "An Evolutionary Theory of Institutions. Prescriptive Implications." *Planning Theory* 10(2): 187–189. https://doi.org/10.1177/1473095210389995

Alfasi, N. 2018. "The Coding Turn in Urban Planning: Could it Remedy the Essential Drawbacks of Planning?" *Planning Theory* 17(3): 375–395. https://doi.org/10.1177/1473095217716206

Aimar, T. 2009. *The Economics of Ignorance and Coordination*. Cheltenham: Edward Elgar. https://doi.org/10.4337/9781781007815

Balint, P. J., Stewart, R. E., Desai, A., and Walters, L. C. 2011. *Wicked Environmental Problems*. Washington: Island Press. https://doi.org/10.5822/978-1-61091-047-7

Batty, M. 2005. *Cities and Complexity*. Cambridge, MA: MIT Press.

Beauregard, R. 2018. "The Entanglements of Uncertainty." *Journal of Planning Education and Research*. https://doi.org/10.1177/0739456X18783038

Ben Joseph, E. 2005. *The Code of the City: Standards and the Hidden Language of Place Making*. Boston, MA: MIT Press.

Brennan, G., and J. M. Buchanan. 2000. *The Reason of Rules*. Indianapolis: Liberty Fund.

Butos, W. N., and T. J. McQuade. 2002. "Mind, Market and Institutions. The Knowledge Problem in Hayek's Thought." Pp. 113–133 in *F. A. Hayek as a Political Economist*. Edited by J. Birner, P. Garrouste, and T. Aimar. London: Routledge.

Bylund, P. L., and M. McCaffrey. 2017. "A Theory of Entrepreneurship and Institutional Uncertainty." *Journal of Business Venturing* 32(5): 461–475. https://doi.org/10.1016/j.jbusvent.2017.05.006

Byrne, P. 1984. *Risk, Uncertainty and Decision-Making in Property Development*. London: E. & F. N. Spon.

Chakraborty, A., and A. McMillan. 2015. "Scenario Planning for Urban Planners: Toward a Practitioner's Guide." *Journal of the American Planning Association* 81(1): 18–29. https://doi.org/10.1080/01944363.2015.1038576

Chiffi, D., and A.-V. Pietarinen. 2017. "Fundamental Uncertainty and Values." *Philosophia* 45(3): 1027–1037. https://doi.org/10.1007/s11406-017-9865-5

Chiffi, D., and A.-V. Pietarinen. 2019. "The Extended Gabbay-Woods Schema and Scientific Practices." Pp. 331–348 in *Natural Arguments:*

A Tribute to John Woods. Edited by D. Gabbay, L. Magnani, W. Park, and A.-V. Pietarinen. London: College Publications.

Chiffi, D., and A.-V. Pietarinen. 2020. "Abductive Inference within a Pragmatic Framework." *Synthese* 197: 2507–2523. https://doi.org/10.1007/s11229-018-1824-6

Choi, Y. B. 1993. *Paradigms and Conventions: Uncertainty, Decision Making, and Entrepreneurship*. Ann Arbor, MI: University of Michigan Press. https://doi.org/10.3998/mpub.13334

Christensen, K. S. 1985. "Coping with Uncertainty in Planning." *Journal of the American Planning Association* 51(1): 63–73. https://doi.org/10.1080/01944368508976801

Cozzolino, S. 2020. "The (Anti) Adaptive Neighbourhoods. Embracing Complexity and Distribution of Design Control in the Ordinary Built Environment." *Environment and Planning B: Urban Analytics and City Science* 47(2): 203–219. https://doi.org/10.1177/2399808319857451

de Roo G., J. Hillier, and J. Van Wezemael (Eds.). 2012. *Complexity and Planning*. Farnham: Ashgate.

de Roo, G., C. Yamu, and C. Zuidema. (Eds.). 2020a. *Handbook on Planning and Complexity*. Cheltenham: Edward Elgar. https://doi.org/10.4337/9781786439185

de Roo, G., W. Rauws, and C. Zuidema. 2020b. "Rationalities for Adaptive Planning to Address Uncertainties." Pp. 110–150 in *Handbook on Planning and Complexity*. Edited by G. de Roo, C. Yamu, and C. Zuidema. Cheltenham: Edward Elgar. https://doi.org/10.4337/9781786439185.00011

Dequech, D. 2000. "Fundamental Uncertainty and Ambiguity." *Eastern Economic Journal* 26(1): 41–60.

Dequech, D. 2001. "Bounded Rationality, Institutions and Uncertainty." *Journal of Economic Issues* 35(4): 911–929. https://doi.org/10.1080/00213624.2001.11506420

Dequech, D. 2006. "The New Institutional Economics and the Theory of Behaviour under Uncertainty." *Journal of Economic Behaviour & Organisation* 59(1): 109–131. https://doi.org/10.1016/j.jebo.2004.03.012

Derbyshire, J., and G. Wright. 2014. "Preparing for the Future: Development of an 'Antifragile' Methodology that Complements Scenario Planning by Omitting Causation." *Technological Forecasting and Social Change* 82: 215–225. https://doi.org/10.1016/j.techfore.2013.07.001

Dyxit, A. K., and R. S. Pindyck. 1994. *Investment under Uncertainty*. Princeton, NJ: Princeton University Press. https://doi.org/10.1515/9781400830176

Ebeling, R. M. 2003. *Austrian Economics and the Political Economy of Freedom*. Northampton, Mass.: Edward Elgar. https://doi.org/10.4337/9781781950098

Edvardsson, K., and S. O. Hansson. 2005. "When is a Goal Rational?" *Social Choice and Welfare* 24(2): 343–361. https://doi.org/10.1007/s00355-003-0309-8

Egidi, M., and L. Marengo. 2004. "Near-Decomposability, Organization, and Evolution: Some Notes on Herbert Simon's Contribution." Pp. 335–350 in *Models of a Man: Essays in Memory of Herbert A. Simon*. Edited by M. Augie and J. G. March. Cambridge, MA: MIT Press.

Emery, F. E., and E. L. Trist. 1965. "The Causal Texture of Organizational Environments." *Human Relations* 18(1): 21–32. https://doi.org/10.1177/001872676501800103

Engel, C. 2005. *Generating Predictability. Institutional Analysis and Design*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511490033

Epstein, R. A. 1995. *Simple Rules for a Complex World*. Cambridge: Harvard University Press. https://doi.org/10.4159/9780674036567

Floridi, L. 2015. "The Politics of Uncertainty." *Philosophy & Technology* 28(1): 1–4. https://doi.org/10.1007/s13347-015-0192-0

Giezen, M. 2013. "Adaptive and Strategic Capacity: Navigating Megaprojects Through Uncertainty and Complexity." *Environment and Planning B: Planning and Design* 40(4): 723–741. https://doi.org/10.1068/b38184

Gigerenzen, G. 2008. *Rationality for Mortals. How People Cope with Uncertainty*. Oxford: Oxford University Press.

Givoni, M., and A. Perl. 2020. "Rethinking Transport Infrastructure Planning to Extend its Value over Time." *Journal of Planning Education and Research* 40(1): 82–91. https://doi.org/10.1177/0739456X17741196

Hajer, M. A., R. Hoppe, and B. Jennings. 1993. *The Argumentative Turn in Policy Analysis and Planning*. Durham, NC: Duke University Press. https://doi.org/10.1515/9780822381815

Haken, H., and J. Portugali. 2014. *Information Adaptation: The Interplay between Shannon Information and Semantic Information in Cognition*. Berlin: Springer. https://doi.org/10.1007/978-3-319-11170-4

Hakim, B. S. 2014. *Mediterranean Urbanism. Historic Urban/Building Rules and Processes*. Berlin: Springer. https://doi.org/10.1007/978-94-017-9140-3

Hansson, S. O. 1996. "Decision Making under Great Uncertainty." *Philosophy of the Social Sciences* 26(3): 369–386. https://doi.org/10.1177/004839319602600304

Hansson, S. O. 2022. "Can Uncertainty be Quantified?." *Perspectives on Science*, this issue. https://doi.org/10.1162/posc_a_00412

Harper, D. A. 1996. *Entrepreneurship and the Market Process. An Enquiry into the Growth of Knowledge*. London: Routledge.

Hayek, F. A. 1948. *Individualism and Economic Order*. Chicago, IL: University of Chicago Press.
Hayek, F. A. 1952. *The Counter-Revolution of Science*. Glencoe: Free Press.
Hayek, F. A. 1982. *Law, Legislation and Liberty*. London: Routledge.
Hayek, F. A. 1988. *The Fatal Conceit*. London: Routledge. https://doi.org/10.7208/chicago/9780226321158.001.0001
Jacobs, J. 1961. *The Death and Life of Great American Cities*. New York: Random House.
Jakee, K., and H. Spong. 2003. "Uncertainty, Institutional Structure and the Entrepreneurial Process." Pp. 125–144 in *Change, Transformation and Development*. Edited by S. Metcalfe and U. Cantner. New York: Springer. https://doi.org/10.1007/978-3-7908-2720-0_8
Kahneman, D. 2011. *Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux.
Kahneman, D., P. Slovic, and A. Tversky (Eds.). 1982. *Judgment under Uncertainty: Heuristics and Biases*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511809477
Kasper, W., and M. E. Streit. 1998. *Institutional Economics*. Cheltenham: Edward Elgar.
Kato, S., and J. Ahern. 2008. "'Learning by Doing': Adaptive Planning as a Strategy to Address Uncertainty in Planning." *Journal of Environmental Planning and Management* 51(4): 543–559. https://doi.org/10.1080/09640560802117028
Katz, D. M., and M. J. Bommarito. 2014. "Measuring the Complexity of the Law." *Artificial Intelligence and Law* 22 (4): 337–74. https://doi.org/10.1007/s10506-014-9160-8
Kimble, J. 1994. "Answering the Critics of Plain Language." *Scribes Journal of Legal Writing* 5: 51–85.
Kirzner, I. M. 1988. "The Economic Calculation Debate: Lessons for Austrians." *Review of Austrian Economics* 2(1): 1–18. https://doi.org/10.1007/BF01539296
Knight, F. H. 1921. *Risk, Uncertainty, and Profit*. Boston: Hart, Schaffner & Marx; Houghton Mifflin Company.
Koppenjan, J., and E.-H. Klijn. 2004. *Managing Uncertainties in Networks*. London: Routledge. https://doi.org/10.4324/9780203643457
Kwakkel, J. H., W. E. Walker, and V. A. Marchau. 2012. "Assessing the Efficacy of Dynamic Adaptive Planning of Infrastructure: Results from Computational Experiments." *Environment and Planning B: Planning and Design* 39(3): 533–550. https://doi.org/10.1068/b37151
Langlois, R. N. 1986a. "Coherence and Flexibility." Pp. 171–191 in *Subjectivism, Intelligibility and Economic Understanding*. Edited by I. M. Kirzner. London: Macmillan. https://doi.org/10.1007/978-1-349-08764-8_13

Langlois, R. N. 1986b. "Rationality Institutions and Explanations." Pp. 225–255 in *Economics as a Process*. Edited by R. N. Langlois. Cambridge: Cambridge University Press.

Langlois, R. N. 2007. "The Entrepreneurial Theory of the Firm and the Theory of the Entrepreneurial Firm." *Journal of Management Studies* 44(7): 1107–1124. https://doi.org/10.1111/j.1467-6486.2007.00728.x

Langlois, R. N., and M. J. Everett. 1992. "Complexity, Genuine Uncertainty, and the Economics of Organization." *Human Systems Management* 11(2): 67–75. https://doi.org/10.3233/HSM-1992-11205

Leoni, B. 1961. *Freedom and the Law*. Princeton: Van Nostrand.

Liebwald, D. 2015. "On Transparent Law, Good Legislation and Accessibility to Legal Information." *Artificial Intelligence and Law* 23: 301–314. https://doi.org/10.1007/s10506-015-9172-z

Loasby, B. J. 1999. *Knowledge, Institutions and Evolution in Economics*. London: Routledge.

McWhinney, W. H. 1968. "Organizational Form, Decision Modalities and the Environment." *Human Relations* 21(3), 269–281. https://doi.org/10.1177/001872676802100304

Moroni, S. 2010a. "Rethinking the Theory and Practice of Land-Use Regulation: Towards Nomocracy." *Planning Theory* 9(2): 137–155. https://doi.org/10.1177/1473095209357868

Moroni, S. 2010b. "An Evolutionary Theory of Institutions and a Dynamic Approach to Reform." *Planning Theory* 9(4): 275–297. https://doi.org/10.1177/1473095210368778

Moroni, S. 2011. "Land-Use Regulation for the Creative City." Pp. 343–364 in *Handbook of Creative Cities*. Edited by D. E. Andersson, A. E. Andersson, and C. Mellander. Cheltenham: Edward Elgar. https://doi.org/10.4337/9780857936394.00025

Moroni, S. 2015. "Complexity and the Inherent Limits of Explanation and Prediction: Urban Codes for Self-Organising Cities." *Planning Theory* 14(3): 248–267. https://doi.org/10.1177/1473095214521104

Moroni, S., and S. Cozzolino. 2019. "Action and the City: Emergence, Complexity, Planning." *Cities* 90: 42–51. https://doi.org/10.1016/j.cities.cities.2019.01.039

Moroni, S., E. Buitelaar, N. Sorel, and S. Cozzolino. 2020. "Simple Rules for Complex Urban Problems. Towards Legal Certainty for Spatial Flexibility." *Journal of Planning Education and Research* 40(3): 320–331. https://doi.org/10.1177/0739456X18774122

Moroni S., and D. Chiffi. 2021. "Complexity and Uncertainty: Implications for Urban Planning." In *Handbook on Cities and Complexity*. Edited by J. Portugali. Cheltenham, UK: Edward Elgar Publishing. https://doi.org/10.4337/9781789900125.00027

Needham, B. 2006. *Planning, Law and Economics*. London: Routledge. https://doi.org/10.4324/9780203639658

North, D. C. 1991. "Institutions." *Journal of Economic Perspectives* 5(1): 97–112. https://doi.org/10.1257/jep.5.1.97

North, D. C. 1995. "Five Propositions about Institutional Change." Pp. 15–26 in *Explaining Social Institutions*. Edited by J. Knight and I. Sened. Ann Arbor: The University of Michigan Press.

Oaksford, M., and N. Chater. 1998. *Rationality in an Uncertain World: Essays on the Cognitive Science of Human Reasoning*. Hove: Psychology Press Ltd.

O'Driscoll, G. P., and M. J. Rizzo. 1985. *The Economics of Time and Ignorance*. London: Routledge.

Olsson, N. O. 2006. "Management of Flexibility in Projects." *International Journal of Project Management* 24(1): 66–74. https://doi.org/10.1016/j.ijproman.2005.06.010

Ostrom, E. 2006. "The Complexity of Rules and How They May Evolve over Time." Pp. 100–122 in *Evolution and Design of Institutions*. Edited by C. Schubert and G. von Wangenheim. London: Routledge.

Pasour, E. C. 1997. "Information, Uncertainty and Choice: Implications for Human Action, Including Public Policy." *Cultural Dynamics* 9(1): 45–61. https://doi.org/10.1177/092137409700900103

Portugali, J. 2008. "Learning from Paradoxes about Prediction and Planning in Self-Organizing Cities." *Planning Theory* 7(3): 248–262. https://doi.org/10.1177/1473095208094823

Portugali, J. 2012. "Complexity Theories of Cities: Implications to Urban Planning." Pp. 221–224 in *Complexity Theories of Cities Have Come of Age*. Edited by J. Portugali, H. Meyer, E. Stolk, and E. Tan. Berlin: Springer. https://doi.org/10.1007/978-3-642-24544-2_13

Portugali, J., H. Meyer, E. Stolk, and E. Tan (Eds.). 2012. *Complexity Theories of Cities Have Come of Age*. Berlin: Springer. https://doi.org/10.1007/978-3-642-24544-2

Ratnapala, S. 1997. "Complexity and the Law." *Agenda* 4(3): 341–350.

Rauws, W. 2017. "Embracing Uncertainty without Abandoning Planning: Exploring an Adaptive Planning Approach for Guiding Urban Transformations." *disP-The Planning Review* 53(1): 32–45. https://doi.org/10.1080/02513625.2017.1316539

Rittel, H. W., and M. M. Webber. 1973. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4(2): 155–169. https://doi.org/10.1007/BF01405730

Salerno, J. (Ed.). 2009. *New Essays on the Knowability Paradox*. Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199285495.001.0001

Salet, W., L. Bertolini, and M. Giezen. 2013. "Complexity and Uncertainty: Problem or Asset in Decision Making of Mega Infrastructure Projects?" *International Journal of Urban and Regional Research* 37(6): 1984–2000. https://doi.org/10.1111/j.1468-2427.2012.01133.x

Savini, F. 2017. Planning, Uncertainty and Risk: The Neoliberal Logics of Amsterdam Urbanism. *Environment and Planning A* 49(4): 857–875. https://doi.org/10.1177/0308518X16684520

Shackle, G. L. S. 1961. *Decision, Order, and Time in Human Affairs*. Cambridge: Cambridge University Press.

Simon, H. A. 1983. *Reason in Human Affairs*. Stanford, CA: Stanford University Press.

Skrimizea, E., H. Haniotou, and C. Parra. 2019. "On the 'Complexity Turn' in Planning: An Adaptive Rationale to Navigate Spaces and Times of Uncertainty." *Planning Theory* 18(1): 122–142. https://doi.org/10.1177/1473095218780515

Smith, V. L. 2008. *Rationality in Economics. Constructivist and Ecological Forms*. Cambridge: Cambridge University Press.

Streit, M. E. 1997. "Constitutional ignorance, spontaneous order and rule orientation". In S. F. Frowen (Ed.), *Hayek: Economist and Social Philosopher*. London: Macmillan. https://doi.org/10.1007/978-1-349-25991-5_3

Stults, M., and L. Larsen. 2018. "Tackling Uncertainty in US Local Climate Adaptation Planning." *Journal of Planning Education and Research*. https://doi.org/10.1177/0739456X18769134

Talen, E. 2012. *City Rules. How Regulations Affect Urban Form*. London: Island Press.

Thompson, J. D. 2003. *Organizations in Action: Social Science Bases of Administrative Theory*. New York: Transaction Publishers.

Van de Poel, I. 2016. "An Ethical Framework for Evaluating Experimental Technology." *Science and Engineering Ethics* 22(3): 667–686. https://doi.org/10.1007/s11948-015-9724-3, PubMed: 26573302

Vanberg, V. J. 2001. *The Constitution of Markets*. London: Routledge. https://doi.org/10.4324/9780203443415

van den Hoek, R. E., M. Brugnach, J. P. Mulder, and A. Y. Hoekstra. 2014. "Analysing the Cascades of Uncertainty in Flood Defence Projects: How 'Not Knowing Enough' Is Related to 'Knowing Differently.'" *Global Environmental Change* 24: 373–388. https://doi.org/10.1016/j.gloenvcha.2013.11.008

Vaughn, K. I. 1994. *Austrian Economics in America*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511572142

Walker, W. E., and V. A. W. J. Marchau. 2003. "Dealing with Uncertainty in Policy Analysis and Policymaking." *Integrated Assessment* 4(1): 1–4. https://doi.org/10.1076/iaij.4.1.1.16462

Webster, C. J., and W. C. L. Lai. 2003. *Property Rights, Planning and Markets*. Cheltenham: Edward Elgar.

Woods, J. 2012. "Cognitive Economics and the Logic of Abduction." *Review of Symbolic Logic* 5(1): 148–161. https://doi.org/10.1017/S175502031100027X

Wubben, E. 1995. "Austrian Economics and Uncertainty: on a Non-deterministic but Non-Haphazard Future." Pp. 106–145 in *New Perspectives in Austrian Economics*. Edited by G. Meijer. London: Routledge.

Xiang, W. N., and K. C. Clarke. 2003. "The Use of Scenarios in Land-Use Planning." *Environment and Planning B: Planning and Design* 30(6): 885–909. https://doi.org/10.1068/b2945

Zandvoort, M., M. J. Van der Vlist, F. Klijn, and A. Van den Brink. 2018. "Navigating amid Uncertainty in Spatial Planning." *Planning Theory* 17(1): 96–116. https://doi.org/10.1177/1473095216684530

Zapata, M. A., and N. Kaza. 2015. "Radical Uncertainty: Scenario Planning for Futures." *Environment and Planning B: Urban Analytics and City Science* 42(4): 754–770. https://doi.org/10.1068/b39059

Zywicki, T. 1998. "Epstein and Polanyi on Simple Rules, Complex Systems, and Decentralization." *Constitutional Political Economy* 9: 143–150. https://doi.org/10.1023/A:1009012111547