Expanding the Use of Scenarios in Geodesign: Engaging Uncertainty of the Anthropocene

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Abstract: Scenario-based approaches are widely accepted aids to decision-making processes. In most cases, scenarios in design provide alternative courses of action, which are evaluated and compared to identify a preferred option. This paper accepts that planning and design frameworks used to create such scenarios structure ambiguity and, thereby, emphasize certain kinds of uncertainty. It is argued that in the context of the Anthropocene and the emergence of associated novel social and biophysical relationships, these uncertainties of conceptualization provide a valuable basis for scenario development. These are referred to as 'scenarios within design'. The geodesign framework is examined as an illustration.

Keywords: Geodesign, design methods, uncertainty, scenarios

1 Introduction

Herbert Simon's often cited, 'Everyone designs who devises courses of action aimed at changing existing situations into preferred ones,' succinctly and generously expresses what design is (SIMON 1996). Arguably less quoted, but fundamental to how design is done, he also helped draw attention to the challenge that design problems are typically ill-defined because, when a problem is first presented, the designer's understanding of initial conditions is incomplete, the goal or end state is open to interpretation, and the procedures or rules to achieve a favourable outcome are not clear (NEWELL et al. 1962). RITTEL & WEBBER (1973) added emphasis to the difficulty of defining acceptable end states with societal issues. They called such problems 'wicked,' because there are no undisputable public goods, no objective definitions of equity, and no definitive answers. As such, a designer who works on these topics is never either clearly right or clearly wrong, but is, nevertheless, responsible for the outcome (PROTZEN & HARRIES 2010).

Concerns about the ill-defined or wicked qualities of problems and their respective uncertainties become increasingly exacerbated when the range of possible options for actions expands, when potential impacts of actions increase, or when the context for making decisions becomes less predictable. These conditions are latent in notion of the Anthropocene, which some have suggested should be considered as our current geological era (BONNEUIL & FRESSOZ 2017, ELLIS 2018). This thesis holds that human capabilities and capacities to change the environment − including agriculture, deforestation, changes to drainage patterns, urbanization, and industrialization − are now the most influential, if not the dominant, factor in the Earth's ecological systems.

Anthropogenic changes to the environment have produced advantages and disadvantages. Shaping and reshaping terrain has enabled larger food supplies, economic growth, and contributed to increasing-, longer living-, and more affluent populations. These benefits, however, have had unintended negative consequences. In turn, a positive feedback loop of these outcomes has resulted in more extensive and more intensive settlement patterns and increased uses of natural resources to meet ever higher demands (WIEDMANN et al. 2020). Further,

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anthropogenic activity has been related to climate change, which includes increasing average high and low temperatures, heatwaves, droughts, more frequent and more extreme storm events, flooding, and sea-level rise (TRENBERTH 2018). Population growth, patterns of settlement, and climate change have also affected the quantities and qualities of habitat for flora and fauna. One consequence has been the emergence of novel ecologies, which are plant communities that include combinations of species never before seen together (HOBBS et al. 2013). A net effect has been not only loss of biodiversity, but what has been called the planet's sixth extinction (KOLBERT 2014).

Beyond these observable impacts, anthropogenic changes are affecting capabilities to anticipates the effects of future conditions. A general principle of systems dynamics is that quantitative change results in qualitative change (CARNEIRO 2000). In brief, once a quantitative threshold is reached, new kinds of relationships among elements or sub-systems become possible. One narrow, but important physical system example is that climate change may result in increasing difficulty to predict precipitation events in the future (SCHER & MESSORI 2019). In social systems as populations grow and resources are increasingly used, efforts to solve problems related to health, safety, and welfare result in the creation of new uncertainty (GIDDENS 1990) and restructured societal risk (BECK 1992).

Across the inherent qualities of today's ill-defined and wicked problems, planners and designers face various and evolving kinds of ambiguity and uncertainty related to the ways, means, and ends of bringing about preferred situations. In this light, there are important questions about how these ambiguities and uncertainties are identified and managed through techniques of practice. The central concern of this paper is to draw attention to some kinds of uncertainties that a designer might need to consider toward opening conversations about the uses of scenarios. Scenarios within geodesign practice is used as a means to advance the discussion.

2 Ambiguity versus Uncertainty in Design

While the expression *ill-defined problem* readily suggests that there are unclear or unknown criteria and conditions, it is not the case that the lacks are all of the same kind or equal in impact. A useful distinction is between *ambiguity* and *uncertainty*.

Looking at technical problem solving, SCHRADER et al. (1994) consider that ambiguity is present when the problem solver is unsure of the set of variables or of relationships among variables and that uncertainty is present when the problem solver is satisfied with the apparent structure and variables of the problem, but is dissatisfied with the understanding of the values of the variables. These authors also put forth the premise that the problem solvers implicitly or explicitly chose to recognize levels of ambiguity and uncertainty by the ways that they go about finding solutions (SCHRADER et al. 1994). Decisions − or defaults − about how much ambiguity and uncertainty might be considered depend on a variety of factors related to the problem solvers' capabilities and the contexts in which they work. Finally, these authors also offer the proposition that ambiguity is best reduced by content-independent measures, but that uncertainty is best reduced by content-specific controls.

One content-independent step to manage ambiguity is the employment of a framework that structures various theories, methods, and practices − such as inventories, indexes, analyses, compositions, evaluations, etc. Frameworks applicable to planning and designing the built environmental have been proposed by many, including ALEXANDER (1964), GRILLO (1960), LAWSON (2006), NEWTON (1951) and ROWE (1987). Selecting one framework over another can be understood as an abstract or even meta-level *abductive conjecture*. The general concept of abduction was introduced in the nineteenth century by the pragmatist philosopher Charles Sanders Peirce (PEIRCE 1934). He suggested that new knowledge developed neither from guaranteed deductive logic nor probabilistic inductive logic, but from a series of incrementally improving abductive best guess explanations from the evidence at hand. In science, the aim is truth and an abductive conjecture is the basis for a formal hypothesis to test relationships about how the world could work. In design, the aim is greater satisfaction and the abductive conjecture is a starting point to test relationships that can be used to change how the world (or at least part of it) should work. The selection of a design framework is, itself, an opening conjecture about how design should help resolve a problem. Nigel Cross, drawing on the work of others, has called attention to the role of *abduction* as the basis for 'designerly ways of knowing' (CROSS 2007).

Given a framework to structure ambiguities, concerns turn to uncertainties. Uncertainty, in a general sense, is present when some sort of information is found to be absent, unreliable, or inexact (FUNTOWICZ & RAVETZ 1990). On the one hand, uncertainty presents problems for decision making, since large or long-term investments are unlikely to be made without confidence of success. On the other hand, it must also be recognized that uncertainty also enables the future to be open and provides possibilities for some forms of desired change (NEY & THOMPSON 2000). BOULDING (1995) identifies four kinds of ways the world can change and related uncertainty. He uses metaphors to make the typology approachable and memorable: planets, plays, plagues, and plants. Planets are aspects of the future that are predictable with great assurance and display very little or no uncertainty. The source of this metaphor are orbits in a solar system. Plays concern interactions among people as they pursue individual and collective goals and objectives. Plagues are difficult to predict, but very impactful, events. Examples include floods, droughts, earthquakes, pandemics, industrial disasters and wars. Finally, plants are aspects of the future that follow a pre-established plan. This category includes societal plans that are put into effect over time. Notably, plants (plans) are not entirely predetermined. While an acorn may become an oak, the size of the tree will and how long it will live remain open issues that will be influenced by a variety of exogenous factors, such as amounts of rainfall, soil characteristics, exposure to disease, etc. As a plant (plan) becomes more complex, so does the uncertainty of its final form and its performance.

With regard to the qualities of ill-defined problems, Boulding does not explicitly mention the designer's difficulty of not fully understanding initial conditions, but he is implicitly in agreement with Simon and with Rittel and Webber that the dynamics of plays can hinder agreements for shared goals. Boulding is in explicit accord with Simon when pointing out that there is uncertainty if desired outcomes will be produced by the plan. More important than these parallels, though, is Boulding's recognition that while the four kinds of change and their related uncertainties can be distinguished for analytic purposes, they interact as widescale social and environmental change is brought about. With regard to design practices, planets will provide some constraints to a new plan (again, a version of a plant in Boulding's typology). An example is maximum solar radiation during the summer or winter months. Atmospheric conditions may limit the reception of energy, but a maximum can be predicted. Also, a plan will be developed and implemented through the uncertain dynamics of plays. Plans will also be informed by an awareness of uncertainties related to plagues to the degree that resilience to disruption is a focal concern.

While Simon identifies core problems of uncertainty related to problem formation and Boulding provides a basis to conceptualize underlying sources of uncertainty related to change, neither qualifies general tools for managing uncertainty. On this topic, COURTNEY et al. (1997) distinguish four situations based on characterizations of possible outcomes that might result from uncertainty. First, aspects of a problem (or the variables of the problem) that are assumed to be certain, or at least, very stable like Boulding's planets, can be addressed with predictions and forecasts. Second, the aspects that are assumed to be uncertain, but have a fixed number of discrete possible outcomes (like the outcomes of rolling a pair of dice) can be addressed with risk analysis in its conventional sense. Third, the aspects that are assumed as uncertain, but have outcomes that fall within a continuous range of possibilities do not provide focal points for analysis (like dice rolls), but can be managed through more sophisticated sensitivity analysis. Finally, aspects that cannot be placed on a spectrum of outcomes, which might include the combinations of high numbers of variables, require techniques to reduce or constrain the uncertainty. One such approach comes through the scenarios developed around critical uncertainties, which are both the least predictable and could have the greatest potential influence on future situations (SCHWARTZ 1996).

3 Scenarios

Scenarios are 'hypothetical sequence[s] of events constructed for the purpose of focusing attention on causal processes and decision points' (KAHN & WIENER 1973). Scenario-based techniques are used in many decision-making contexts to structure thoughts about how events might unfold and to assess their related consequences. Figure 1 provides a diagram of the premise. The long line with arrows pointing left and right represents time. The grids on the line represent a mapping of conditions relative to two issues. Each issue is represented by one axis of the grid. While only two axes are illustrated for graphic simplicity, more issues might be considered. In the centre of the figure, the open dot represents present conditions relative to the issues. Mappings of the same issues in the past are charted on the grids to the left. The multiple lines connecting dots reflect the proposition that people may have differing opinions on the causal path of change from one point in time to another. Dashed lines to the right of the present represent scenarios about what could or should occur in the future. The grids represent key moments in time for comparison and assessment. The dots on the grids represent alternative futures based on the causal logic of the scenarios.

Given the range of applications, numerous ways to categorize kinds of scenarios and methods of scenario development have been made (BÖRJESON et al. 2006, VAN NOTTEN et al. 2003, WILKINSON & EIDINOW 2008). A full review of this literature is not necessary for this paper, but ideas about uncertainty in a scenario-based process must by highlighted. While scenarios are commonly used in situations with high uncertainty – high with regard to the understanding of initial conditions, the desired end state, or procedures to bring about that end state − they might also be employed when there is relatively low uncertainty in order to array combinations of actions. Regardless, once uncertainty is acknowledged, there is the need to do some kind of assessment with regard to what is possible or, more narrowly, what is plausible. Such assessments might be grounded explicitly by evidence from past precedent; accordance with laws, regulations, or customs; or known physical or biophysical limits. The assessments might also be based on the intuition of the scenario developer. Scenarios that include information that detracts from possible and plausible causal paths between the present and alternative futures are unlikely to receive full consideration by decision makers (SHEARER 2013). That said, to the degree that a scenario-based process aims to advance organizational learning, scenarios must also offer novelty alongside plausibility (WACK 1985). Without such novelty, the decisions will be based on routine criteria that ignore the emergence of novel conditions. This plausibility-novelty balance must extend across scenario authors, scenario users (decision makers), and the larger set of stakeholders who will be impacted by actions taken (SCHMIDT-SCHEELE 2020).

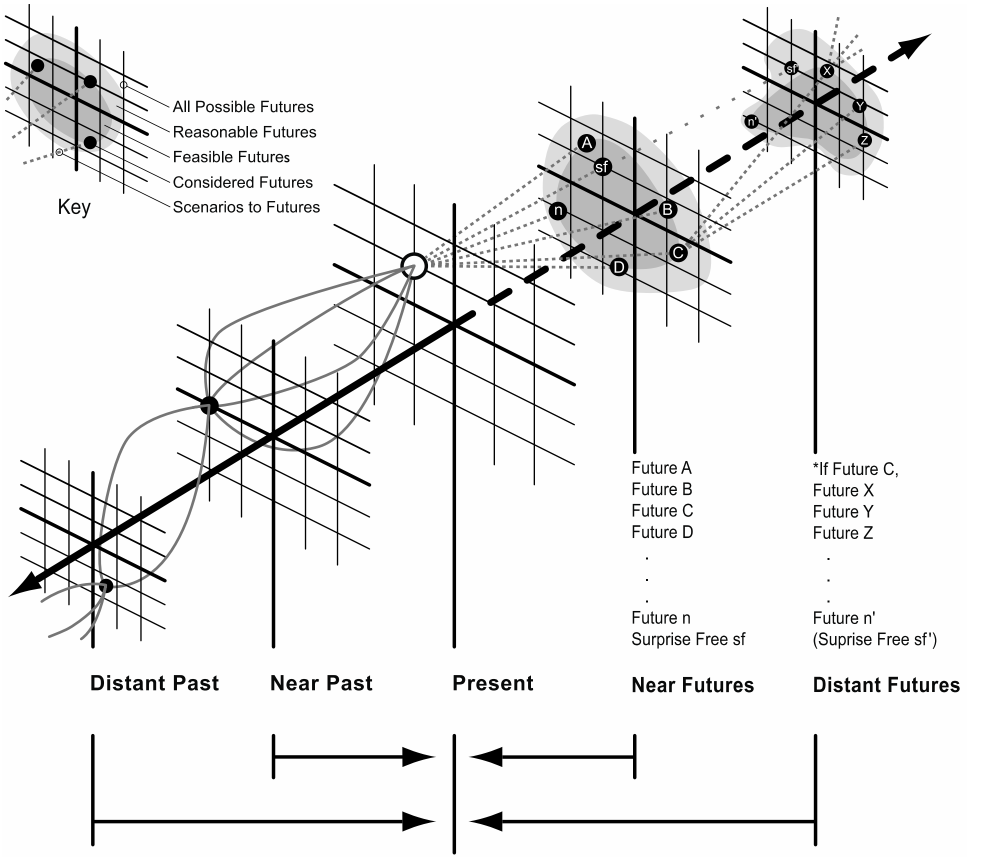

Fig. 1: Scenarios and alternative futures (originally published in SHEARER, A.W. (2005), Approaching Scenario-Based Studies: Three Perceptions about the Future and Considerations for Landscape Planning. *Environment and Planning B: Planning and Design* 32 (1), 67-87, this figure p. 71. Reused with permission from SAGE.)

Not all uncertainties receive the same level of scrutiny or serve to frame the logic of causation in a scenario-based process. Rather than chart every conceivable future, scenarios focus on *critical uncertainties*, which, as noted above, are those aspects of the future which are both the least predictable and could have the greatest potential influence on future situations. While some scenarios may share features, they are ultimately distinguishable from one another by significant mutually exclusive assumptions. A set of such scenarios then offers an array of meaningfully different combinations of conjectures and provides a decision-making aid to apprehend interactions of multiple variables across the perceived problem.

While the phrase *design scenarios* might be used as a catch-all phrase to encompass all kinds of scenarios for all kinds of planning and design projects, this paper will introduce two expressions to distinguish uses of scenarios. As a shorthand expression, the first kind of use is called *scenarios of thinking* or *scenarios of designs*. In this kind of use, an individual scenario combines several "if…, then…" conjectures about the occurrence of future happenings and their consequences within the control of the designer and stakeholders. Importantly with this kind of scenario, the underlying logic of (1) assessments about present conditions and (2) possible actions that might be taken to purposefully bring about a better situation can be assumed with reasonable confidence. Arraying the scenarios is needed, though, to provide a comparative assessment of the consequences of each alternative and evaluate the best path forward given available means.

The second kind of use is called *scenarios within thinking* or *scenarios within design*. In this approach to scenario thinking, scenarios are used to scrutinize individual assumptions as part of an organizational learning process (RAMIREZ & WILKINSON 2016, VAN DER HEIJDEN 2005). That is, rather than consider sets of what might be considered uncontroversial 'if…, then…' conjectures, narrow aspects of the problem or its possible solutions are examined by exploring the logic of how a given 'if…' results in a corresponding 'then….' The conjectures can include assumptions that are descriptive, evaluative, predictive, or explanatory (DEWAR et al. 1993). The salient features of these assumptions, though, is that they are not settled.

In spatial planning and design practices, *scenarios of thinking* or *scenarios of design* are commonly used to assemble and examine alternative possibilities about means of change that can be controlled by stakeholders. Common factors include differences in materials, locations, dimensions, and configurations or about the timing or sequence of proposed changes (GOODSPEED 2020). In these instances, the scenarios, themselves, are normative, because each presents an assumed image for a preferred condition for assessment and comparison. *Scenarios within thinking* or *scenarios within design* are sometimes used in other instances to explore alternative sets of assumptions that are beyond significant influence by stakeholders, but that may affect the success of a plan or design. That is, these scenarios support a kind of geographic vulnerability analysis for local initiatives. Common factors in these instances include climate change, population and demographic characteristics, the state of the macroeconomy, regional or national regulatory policy, or the introduction of new technologies (SHEARER et al. 2009). These kinds of scenarios are also part of normative planning and design practices, since they contribute to identifying preferred outcomes; however, these scenarios are considered to be descriptive (not normative), since reflect exogenous uncertainty.

It is not controversial to say that formal processes to compare strategic options and future contexts are beneficial, but it must also be admitted that the quality of any decision-making aids are only as good as the thinking used to develop them. Also, while *scenarios of thinking* and *scenarios within thinking* are useful, the opinion is offered that *scenarios within thinking* techniques are increasingly valuable as the context decision-making become less predictable and the consequences of decision-making more influential-as in the conditions of the Anthropocene. The position taken in this paper is that previously unexperienced present conditions and emerging complex interactions of biophysical-, social-, and cyber/information systems call into question the ability to rely on precedent and notions of conventional wisdom in architecture, landscape architecture, urban design, and regional planning. As such, there should be greater consideration of uncertainties within design processes. A proposition for doing is increased use of *scenarios within thinking*. Rather than producing (or only producing) *scenarios of designs* for final assessment by stakeholders and decision makers, the call is for *scenarios within design* processes for consideration by design teams. Using such scenarios to develop design options would provide for a kind of sensitivity evaluation of key details. More significantly, using scenarios would open and formalized conversations about assumptions that contribute to more robust design.

4 Geodesign

This paper uses the geodesign framework to begin a consideration of *scenarios within design*. The approach of geodesign to structure ill-defined problems and tame wicked ones is advantageous as a basis for initial exploration of uncertainty within design for three reasons. First, the geodesign framework is explicit with regard to +the ways an understanding of a problem is recognized and resolved (STEINITZ 2012). Second, it has been applied to a wide variety of design problems around the world and is currently being used as the basis of an international collaboration of planning and design educators to gain insights on the ways priorities and constraints are managed in different demographic, governmental, and climatic contexts (FISHER et al. 2020). Third, with respect to Simon's notion of who designs, geodesign calls for collaboration among the people of an area, geographic scientists, information technologists, and professional designers, each of which may have different notions and priorities of uncertainty (STEINER & SHEARER 2016). Overall, the breadth and depth of the geodesign approach over a sustained period of time is evidence of the framework's usefulness. Its relative advantages or disadvantages in comparison to other design frameworks is not the focus of the present discussion. It is offered, though, that careful examination of any design framework can provide lessons that are transferable for investigating other frameworks.

The geodesign framework, which is illustrated in Figure 2, was developed by Carl Steinitz to help teach design methods to students of landscape architecture and allied disciplines (STEINITZ 1990). In it, six interrelated questions are asked. Each question is answered by a model of understanding. Each model reflects theoretical perspectives, implementable methods, and practical techniques for providing the needed answers. The questions are asked and answered three times (and sometimes more).

Presenting the questions from the top to the bottom of the diagram, the first three questions concern existing conditions and the second three concern possible change. The first question is, 'How should the study are be described?' The answers are representations of existing conditions. Representation model answers are typically spatially explicit and include biophysical and socio-political-economic features. Given representation models, the second question is, 'How does the study area work?' Process model answers describe functional relationships between or among the representation models. For example, the process of surface runoff would include features including surface cover, soil qualities, slope, and the characteristics of a precipitation event. Given process models, the third question is, 'Is the study area working well?' Evaluation model answers are used for assessments of current conditions.

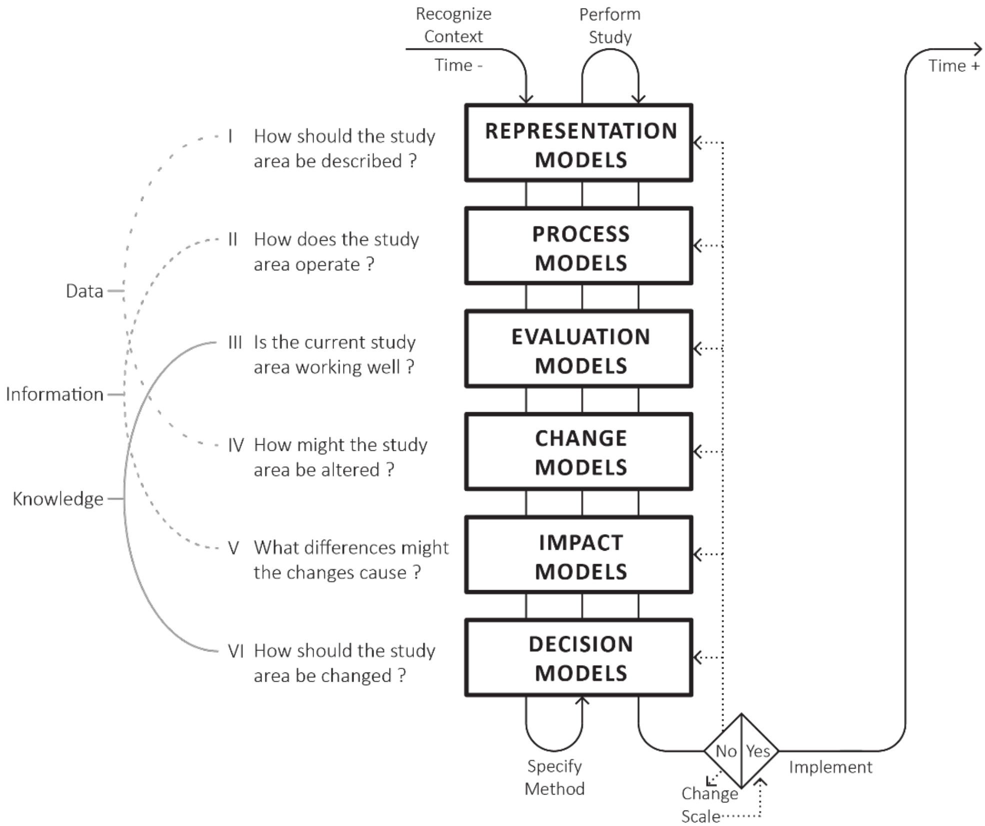

Fig. 2: Framework for geodesign (redrawn from STEINITZ, C. et al. (2003), *Alternative Futures for Changing Landscapes: The Upper San Pedro River Basin in Arizona and Sonora*. Island Press, Washington, D.C., USA, p. 14)

Given the evaluation models and turning to possible futures, the fourth of the six questions is, 'How might the study area change?' Change model answers describe possible future conditions. As the geodesign framework is commonly employed, the alternative proposals are what most would consider 'the designs.' In the phrasing used in this paper change models are *scenarios of thinking* or *scenarios of design*, because they convey a set of conjectures (informed by theories of planning and design and compositional methods) about how to improve the current situation. Given change models, the fifth question is, 'What differences might the changes cause?' Impact model answers use the same functional relationships used for process models, but employ variables parameterised from the scenarios of design rather than from the existing conditions. Finally, given impact models, the sixth question is, 'How should the study are be changed?' Decision model answers provide the rationale to assess the scenarios and move forward to act on the preferred proposition for change.

As mentioned above and as illustrated by the time line that runs through the framework's six models, the questions are asked three times (and perhaps more). In the first iteration, the questions are asked and answered in the order described above.

The second iteration is, perhaps, the most important. Given the provisional answers, this pass provides everyone involved with an opportunity to reflect about what kinds of additional or better representation, process, evaluation, change, impact, and decision models are needed. The questioning begins with the decision model and proceeds in reverse order. So, given an initial understanding of what might be presented to decision makers, what are the needed qualities of a decision model − what are thresholds of 'preferred' or 'better' outcomes and how are they demonstrated? Then, given criteria to proceed with making changes to the study area, what are the needed qualities of impact models? Given the criteria of the impact models, what are the needed qualities of change models? Given criteria of change models, what are the needed qualities of evaluation models? Given criteria of evaluation models, what qualities of process models are needed? And, given criteria of process models, what are the needed qualities of representation models? This order emphasizes that the geodesign framework is decision-driven, not data-driven. In the third iteration, the questions are again asked from top to bottom. Additional sequences of questions and answers might be asked if and as thresholds to support decision making are not met.

5 Uncertainty in Geodesign

As mentioned, in the geodesign framework, change models conventionally contain what have been called in this paper *scenarios of thinking* or *scenarios of designs*. They convey sets of mutually exclusive assumptions about the locations, dimensions, and materials of items in the project area. The scenarios may also include the timing and sequence about when new items are introduced to the site. *Scenarios within thinking* would be used to examine uncertainties of understanding. In the case of geodesign, kinds of uncertainty related to underlying assumptions are rooted in the arcs on the left side of the framework diagram. Observations and projections about the landscape in space and in time are treated as *data*. Relationships between or among data through cause-and-effect relationships are kinds of *information*. Assessments with regard to the performance of present or future status of the cause-and-effect relationships are kinds of *knowledge*.

The consideration of these kinds of uncertainties will be structured from the bottom to the top of the geodesign framework to reflect that it is in this direction that the 'design techniques are designed' in the second pass of the six questions.

5.1 Evaluation and Decision Models: Moral Uncertainty

How is the preferred end state condition to be recognized? This question − a common concern to SIMON, RITTEL and WEBBER − is subject to moral uncertainty. It may also be subject to a kind of aesthetic uncertainty in instances where qualities of appearance are significant but are contested by stakeholders. In some instances, the matter will be settled by governmental policy and regulatory requirements. For example, process models of ozone production would allow predictions of air quality status relative to standards required by different levels of government (LENTS 1998). Such policies and benchmarks, though, are rarely permanently settled matters and there is increasing attention to conflicts within and across landscape governance systems (SCOTT 2011, SAUNDERS & CORNISH 2021). Normative planning and design paradigms, such as sustainability, resilience, and the recent notion of antifragility, can also present conflicting directions for action (KOHLERS 2016, REDMAN 2014). Scenarios to man age moral uncertainty might pose alternative values and interests to examine who or what not only directly benefits from the possible changes. Scenarios of decision-making processes and governance structures are not easily found in the geodesign literature, but are made in other domains to examine alternative approaches for how to shape the environment and manage resources (for example: KUZDAS & WIEK 2014, PARSON & REYNOLDS 2021).

Following from the premise that the geodesign framework is decision-driven, the conceptualization and identification of uncertainty with regard to decision criteria will frame the kinds of change that might be considered. Referring back to Boulding, the changing interrelationships of uncertainties among plays, plants (plans), and plagues leads to a consideration of anthropological or sociological positions to uncertainty. An approach to recognize some implications is provided by RATHBUN (2007), who distinguished four schools of thought about how notions of uncertainty contributed to international relations. The underlying principles are generally applicable to negotiation and decision making and can inform an understanding on postures for environmental planning and design. The first school of thought is *realism*. Uncertainty in it stems from a fundamental inability to know what might occur or what others might do. The realist response is motivated by fear and often takes the form of preparing for conflict by acquiring increased power − bigger militaries in international relations, larger infrastructure projects in environmental design. The second school is *rationalism*. While uncertainty in it also stems from a lack of information, there is an assumption that possible actions of others could be known. The rationalist response to overcome ignorance is increased transparency, monitoring, and signalling among actors. Environmental design responses can include regional cooperation and disclosures. The third school is *cognitive*. It locates uncertainty in complexity that is too difficult to resolve. The cognitivist response is to remove sources of confusion, usually by increased technical know-how that is shared among stakeholders. Environmental design responses under the school of cognitivism include various forms of zoning, such as Euclidean zoning (named after the town of Euclid, Ohio, USA) that segregates land uses within a municipal area, form-based zoning that regulates the size and shape of buildings irrespective of their use, and performance zoning that prescribes criteria for how a building or landscape functions vis-à-vis established goals (ELLIOTT 2008). In each case, the goal is to manage spatial, volumetric, and/or operational aspects of the built landscape while recognizing that not all possible arrangements or patterns can be predicted. The fourth school is *constructivism*. It locates uncertainty in ambiguity that results from indeterminacy related to the lack of conventions. The constructivist response is to prescribe normative behavior and to ascribe agreed upon meaning to terms and actions. It assumes that identity is socially constructed and that behavior is socially enabled (or correspondingly constrained). An equivalent concern in environmental management is finding a common and practicable definition of sustainability (OWENS 2003).

Following Rathbun, the perception of uncertainty is entwined with understandings about preferred courses of action. With regard to the geodesign framework, considering *scenarios within design* modeled as alternative schools of thought as bases for decision models could result in very different *scenarios of design*. More nuanced comparisons of change models might also be done since the alternative decision models might also be the basis for alternative evaluation and impact models. If so (and assuming a common or relatable representation models could be used across all impact models), it could be asked how each of the spatialized scenarios are ranked in the respective sets of impact models. That is, while rationalist and cognitivist schools have different assumptions about how the world works, do they share a net assessment about a preferred course of action?

5.2 Process and Impact Models: Epistemic Uncertainty

Cause-and-effect relationships describe expectations about what is possible (SOLMAN 2005). Epistemic uncertainty exists due to limits, possible flaws, or gaps in the understanding of these relationships. As a matter of clarification, epistemic uncertainty is more than variation in the observable world, which is aleatory or statistical uncertainty. Epistemic uncertainty concerns fundamental or systemic unknowns about causation. These issues can be found within a discipline or sub-field, and they are also found, and are perhaps more substantive, across disciplines in which the ways knowledge is produced and substantiated differ (RENN 2008). Issues of epistemic uncertainty underscore increasing attention to concerns about governance in times of disruption and strategies of resilience, where the central question is how might societies know how to anticipate greater magnitudes or new kinds of disturbance and adapt (CHANDLER 2018, CHANDLER et al. 2020). However, alongside this interest, it has been argued that perceptions about expertise, including how it is developed and applied, are changing. Throughout the Modern period, new uncertainty and risk have been managed through the application of scientific insight and expert opinion, but pressures of our current situation have prompted an assessment of our current era as a 'Post-Normal Time,' because we are between periods of orthodox thinking about how to address problems (SARDAR 2010). This situation can intensify difficulties of decision making.

In design practices, epistemic uncertainty prompts questions about how can the designer know if the design will serve it purpose (GALLE 2011). In geodesign, these relationships are typically represented as quantified and spatialized systems models. Generally, models of biophysical and social processes (including coupled biophysical-social processes) are also open to validation and comparison (KIRCHNER 1996). A simple example is competing models about the way water flows over terrain. In such an instance, scenarios could be developed based on results from alternative models of flow or alternative parameterisation within a given model (KHAN & ORMSBEE 1989).

5.3 Representation and Change Models: Ontologic Uncertainty

Many uncertainties related to representations in design are based in issues of accuracy and precision. For this discussion, accuracy concerns whether or not the measurement is 'true' to the object it represents; precision concerns the resolution of the measurement. In addition to problems created by inaccurate and imprecise dimensions, larger ontological questions about what is represented and classification schemes in design process can have profound influence on results. For example, how many land uses are included? How is membership in a class decided? If an entity is not represented or not adequately represented, it cannot be a factor in future decisions. Membership in an individual class is often absolute (that is, an entity is a member or not) and Boolean logic is utilized to render how entities that share characteristics. This approach, though, can overly simplify how an entity is presented and implicitly overstate accuracy.

An example can be found in a geodesign study of Southern California. (STEINITZ et al. 1996). In the United States, soil maps are issued by the federal government, but are mapped at the county-level of individual states. This study area included parts of three counties. It was evident that along part of one boundary, the soil hydrologic groups were assigned one value in one county and different value in the adjacent county. While it could be assumed good faith efforts by both county mapping teams, the classifications offered by each differed. The researchers (designers) had to take the results as-is, but their results were exposed to an error on one side of the line or the other. In this instance, scenarios would substitute variables so that the figure was the same on both sides of the county line as baseline data.

6 Discussion and Conclusions: Uncertainty and the Politics of Vulnerability

In the context of the Anthropocene and the world's rapidly evolving systems, the task of transforming current situations into preferred ones seems increasingly daunting. Cumulative decisions about how to shape the environment and utilize natural resources made since the start of agriculture and then intensified with the industrial revolution have resulted in challenges societies now face (RUDDIMAN 2005). More change is needed, but it will need to be change made with greater consideration of immediate-, mid-, and long-term effects and with an awareness of what is not certain. Design frameworks, such as the geodesign framework, serve to structure ambiguity in ill-defined problems and, thereby, enable decisions to be consistently reasoned, but content-specific uncertainties are embedded within all such structured approaches. Ignoring critical uncertainties related to the provision of health, safety, and welfare risks being wrong about societally important issues and may perhaps cause increased harm.

It might be argued that *scenarios within design* can be reduced to a form of sensitivity analysis done in support of decisions about composition, which is what many consider to be the primary task of design. The counter position − that is, that s*cenarios within design* are needed as part of contemporary design processes − stems from a general recognition of the complexity of interrelated social and biophysical systems and a specific tenet of design practices that call for participation by local stakeholders and subject matter experts as collaborators and not just resources. Simply put, if a design process values participation, it should accommodate the messiness that everyone brings as they, too, attempt to balance plausibility and novelty in scenarios for making decisions. More emphatically, to not include the kinds of uncertainties studied, worked through, and lived by others diminishes the contributions they might make to resolve ill-defined problems.

In addition to kinds of uncertainty, it is also possible to discuss degrees of uncertainty. Some uncertainty is personally inconvenient. An example concern about being on time for a meeting. Failure might result in missing the start of a film or the loss of a business contract, but the consequences are localized and personal steps can be individually addressed by setting alarms and allowing for extra time to arrive. A higher degree of uncertainty concerns societal wellbeing through the provision of collective health, safety, and welfare. Devising methods and procedures to do so typically falls to licensed professionals and governmental oversight. Importantly, the solutions are socially and politically agreed upon and enforced. Examples are found in traffic signals at roadway intersections. While such uncertainty is not completely eliminated, risks are considered to be manageable. Uncertainty can also escalate to become existential. The notion of environmental security captures concerns that not only can degraded and volatile ecological conditions result in societal disruption and human death, but that extraordinary security measures beyond the societal balances enabled by open political debate might be needed to address them (BRIGGS & MATEJOVA 2019). A characteristic of the Anthropocene is an increase in existential uncertainty for many and devising change to ameliorate current stresses and prevent others from occurring will require addressing uncertainty across data, information, and knowledge. Design techniques that can consider such kinds of uncertainty are needed.

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