Translational Systems Sciences 8

Peter Jones · Kyoichi Kijima *Editors*

Systemic Design

Theory, Methods, and Practice

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Translational Systems Sciences

Volume 8

In 1956, Kenneth Boulding explained the concept of General Systems Theory as a skeleton of science. He describes that it hopes to develop something like a "spectrum" of theories—a system of systems which may perform the function of a "gestalt" in theoretical construction. Such "gestalts" in special fields have been of great value in directing research towards the gaps which they reveal.

There were, at that time, other important conceptual frameworks and theories, such as cybernetics. Additional theories and applications developed later, including synergetics, cognitive science, complex adaptive systems, and many others. Some focused on principles within specific domains of knowledge and others crossed areas of knowledge and practice, along the spectrum described by Boulding.

Also in 1956, the Society for General Systems Research (now the International Society for the Systems Sciences) was founded. One of the concerns of the founders, even then, was the state of the human condition, and what science could do about it.

The present Translational Systems Sciences book series aims at cultivating a new frontier of systems sciences for contributing to the need for practical applications that benefit people.

The concept of translational research originally comes from medical science for enhancing human health and well-being. Translational medical research is often labeled as "Bench to Bedside." It places emphasis on translating the findings in basic research (at bench) more quickly and efficiently into medical practice (at bedside). At the same time, needs and demands from practice drive the development of new and innovative ideas and concepts. In this tightly coupled process it is essential to remove barriers to multi-disciplinary collaboration.

The present series attempts to bridge and integrate basic research founded in systems concepts, logic, theories and models with systems practices and methodologies, into a process of systems research. Since both bench and bedside involve diverse stakeholder groups, including researchers, practitioners and users, translational systems science works to create common platforms for language to activate the "bench to bedside" cycle.

In order to create a resilient and sustainable society in the twenty-first century, we unquestionably need open social innovation through which we create new social values, and realize them in society by connecting diverse ideas and developing new solutions. We assume three types of social values, namely: (1) values relevant to social infrastructure such as safety, security, and amenity; (2) values created by innovation in business, economics, and management practices; and, (3) values necessary for community sustainability brought about by conflict resolution and consensus building.

The series will first approach these social values from a systems science perspective by drawing on a range of disciplines in trans-disciplinary and cross-cultural ways. They may include social systems theory, sociology, business administration, management information science, organization science, computational mathematical organization theory, economics, evolutionary economics, international political science, jurisprudence, policy science, socio-information studies, cognitive science, artificial intelligence, complex adaptive systems theory, philosophy of science, and other related disciplines. In addition, this series will promote translational systems science as a means of scientific research that facilitates the translation of findings from basic science to practical applications, and vice versa.

We believe that this book series should advance a new frontier in systems sciences by presenting theoretical and conceptual frameworks, as well as theories for design and application, for twenty-first-century socioeconomic systems in a translational and transdisciplinary context.

More information about this series at http://www.springer.com/series/11213

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This book is dedicated to the memory of Dr. Ranulph Glanville, former president of the American Society for Cybernetics and fellow traveler with the authors in this volume, connecting the systems disciplines through his life and career. To Ranulph, design and cybernetics were two different sides of constructivist sensemaking in the world, and not separate disciplines as we are schooled to believe. I learned from him the understanding of cybernetics and systemic problems led to designing, as the most befitting course of informed action. Ranulph spent much of the last decade of his career bringing these fields together, very clearly in several essays and talks, including his final public lecture at Relating Systems Thinking and Design (RSD3) in October 2014.
Dr. Glanville's inclusive insistence on co-informing theory and practice across cybernetics, systems thinking, and design inspire values shared by many of us seeking wiser ways across related fields of practice today.

Design and systems theory both gain from the influence of timeless ideas, the cross-appropriation between frameworks and models, and the intimate and often guild-like relationships with leading practitioners. These chapters call forth too many authors and thinkers to recognize with concision here, but if we were to list the most influential first- and second-generation leaders in design and systemics, I might suggest we acknowledge Ross Ashby, Gregory Bateson, Buckminster Fuller, Margaret Mead, Herbert Simon, Fred Emery, Eric Trist, Heinz von Foerster, Hasan Özbekhan, West Churchman, Christopher Alexander, Horst Rittel, Stafford Beer, Erich Jantsch, Alexander Christakis, John Warfield, Gordon Pask, Humberto Maturana, Russell Ackoff, Charles Owen, Victor Papanek, and of course Harold Nelson, a co-founder of RSD.

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Preface: Taking Stock and Flow of Systemic Design

The following book is an edition in the Springer Translational Systems Sciences series and addresses the continuing development of systems theory and methods for complex design contexts. This volume aims to make progress towards a continuing absence in the systems sciences and the discontinuity of design as theory and method for innovation, change, and process implementation. Systems and cybernetics practices have made several notable attempts to resolve this discontinuity, some with extensive publishing and project track records and others more quietly successful.

Systemic design has emerged to address this developing interdisciplinary area of practice, growing from leadership within design studies and its intersection with systems sciences through dedicated collaboration and respectful cross-appropriation. The nine chapters published in this collection were developed by authors from the proceedings of the fourth Relating Systems Thinking and Design (RSD) symposium[1] held in Banff, Canada, in 2015. These authors clearly overlap and share multiple influences and earlier systems programmes that have led to the recent confluence of systems thinking and design.

The broad fields of design and systems have both historically presented approaches to general-purpose problem solving, with domain-independent methodologies based on design rationale (Moran & Carroll, 1996) or scientific principles (Simon, 1962) for holistic problem solving (Fuller, 1969; Jones, 2011). As "thinking" modes, both design thinking and systems thinking promise effective, cross-disciplinary approaches to complex problem resolution. Perhaps, the most prominent interdisciplinary approaches of systemics and design thinking were developed in the Ackoff and Banathy-era social system design schools that promoted whole system approaches to the challenges of the modernist technological era.

[1]Ryan, A., & Jones, P. (2015). *Proceedings of Relating Systems Thinking and Design (RSD4) 2015 Symposium*. Banff, Canada, September 1–3, 2015. systemic-design.net/rsd-symposia/rsd4-proceedings

The systems science origins of systemic design can be traced to the influential operations research and planning schools, the East Coast schools (Ackoff, Özbekhan from University of Pennsylvania, Senge from MIT), and the West Coast (Horst Rittel, C. West Churchman, Christopher Alexander, and Harold Nelson all from U.C. Berkeley). Social systems theory and methods, perhaps the first inclusion of systemics as a design practice, evolved from the 1970s following the Club of Rome prospectus titled *The Predicament of Mankind* (Ozbekhan, 1970). We can trace references and ideas from today's systemic design from the social systems methodologies that followed in this era, such as Peter Checkland's soft systems methodology (1975), Erich Jantsch's evolutionary design (1973), Russell Ackoff's idealized design (1985), Bela Banathy's social system design (1997), John Warfield's generic design science (1985), and Alexander Christakis' dialogic design (2006). All of these projects shared approaches and values in common, such as a strong orientation to boundary and perspectives as opposed to problem solving, post-positivist (or constructivist) epistemologies, the adaptation of complementary modes of thinking, and the necessity of stakeholder participation.

These social schools of thought argued against many of the precepts of the predominant systems thinking methods of the time, systems thinking as modelling and intervention (Meadows, 1999), and systems dynamics (Senge, 1986). Social system design did not achieve the broader acceptance of hard systems sciences, in part due to the superior fit of the hard systems thinking mindset to modernist culture in the late twentieth century and the perceived ambiguity (and lack of method) of social systems processes and technologies.

However, on behalf of design scholars and professionals, I might argue that the design functions of the social systems methodologies were not ever designed for the human uses and applications needed from extensive sociotechnical development projects. Social systems never evolved to become "designerly"; with its roots in systems theory, its applications remained too abstract and removed from human behaviour. For too long we have included design thinking as a peripheral passenger in the systems journey, following along with the Herbert Simon definition of design as a "move from a current situation to a preferred situation.[2]" If we do not fully embrace designing as an advanced way of knowing and enacting with the sociomaterial world, we risk failure in desired transformation.

The recent designerly turn in systems thinking must credit Buckminster Fuller's early exploration (1960s) of what we now call transdisciplinary design, in his "comprehensive anticipatory design science" for complex problems of industrial production, transportation, habitation, and environmentally sensitive design. At least three other significant designers from the 1970s era, architect Christopher Alexander, Victor Papanek (with critical social design), and John Chris Jones (design methods originator), influenced a new generation of designers. Their design practices were well integrated and did not reveal much in the way of formal cybernetics and systems theory, even if their approaches were deeply informed by systemics. We recognize this integration of knowledge, experience, and sensitivity as the "designerly

[2] Simon, Herbert A. (1969). *The sciences of the artificial*. Cambridge, MA: MIT Press, p. 130.

way of knowing," as Nigel Cross (2002) has referred. Perhaps, the designerly aim might be to emulate these designers for their integrated practices and not to disclose the many, possibly confusing, contributing references making up the practice.

Systemic design draws on the wellspring of a half-century of discourses from both systems theory and design practices, fruitfully developing a research base and new methods. It provides a welcoming field for emerging design practices to plant theoretical ideas that reach across disciplines. Several recurring precedents in the evolution of systemic design are prominent within these chapters and symposia, including:

- Design cybernetics, especially second-order reflexivity in design practice (Glanville, 2009; Krippendorff, 2007)
- Design thinking for wicked problems (Buchanan, 1992)
- Systems-oriented design (Sevaldson & Vavik, 2010)
- Systemic design approach to ecological design (Bistagnino, 2011)
- Product-service systems (Manzini & Vezzoli, 2003; Morelli, 2002)
- Transformation design (Sangiorgi, 2011)
- Transition design (Irwin, 2015)
- Dialogic design (Christakis, 2006)
- Design for conversation (Dubberly & Pangaro, 2015)
- DesignX (Norman & Stappers, 2016)

Design is an essential partner in transformative projects and is an essential mindset and discipline when facing "actual" wicked problems—the sort that Rittel meant as contexts that resist problem-solving mindsets. These situations, messes and meta-messes, require our capacity to rethink received notions, to reframe and redirect, to creatively inquire, to engage many skills and senses, to powerfully communicate central ideas to others, and to produce campaigns for change. We may reform, improve, innovate, or otherwise *design* systems but fail to change outmoded cultures, create effective new practices, or inspire positive norms. We also risk losing the unique critical power of systems thinking to transform organizations and practices when advancing theories of change without fully integrating design. Systemic design advances an integrative interdiscipline with the potential to implement systems theory with creative methods and mindsets, by bringing deep technical knowledge, aesthetic skill, and creative implementation to the most abstract programmes of collective action. The cases and practices in the following chapters attest to these new modes of thinking and acting with stakeholders on such problem domains, in healthcare, urban development, informatics, and public service.

Relating Systems Thinking and Design

For 7 years, the Relating Systems Thinking and Design (RSD) symposium has convened a design-oriented conference to develop the intersection of systems science and theory and design practice, methods, and education. This intersection between systemics and design has not been addressed by other scholarly or practitioner conferences, as these two fields have actually drifted apart while often invoking the languages of "systems" and "designing" without truly understanding the core methods of each discipline. We have aimed to develop a strong relationship between the disciplines that brings out the best in each tradition.

Systemic design has developed through integration of design research programmes at several universities participating in the RSD symposium series. These schools have evolved systems-oriented design programmes for roughly a decade, in some cases longer, in search of powerful approaches to transdisciplinary design for complex sociotechnical contexts. While a small number of design scholars have worked and thrived rather naturally in this intersection throughout their careers, awareness of the import of systems thinking was fragmented and inconsistent across design specializations. There was no common understanding of a practice or a canon of theory for design applications. In fact, judging by the prevailing popular themes at design and systems conferences, the fields were continuing to drift apart. Design and architecture have been moving into advanced service and interaction design for big data, urban systems (e.g. smart cities), healthcare, and other complex systems applications, but without a foundation of systems methods or well-understood cybernetics concepts. Similarly, in systems thinking and sciences, the increasing attention to organizational, service, and social systems led to new models and theory, but little design of prototypes or exemplary applications. These gaps appeared as far more than missed opportunities for a complete design discourse, but rather as the necessary emergence of an integrated discipline better adapted to our problems than its component disciplines.

The symposium expresses an intent as "relating" two worlds, between two wide-ranging, continually contested disciplines of systems thinking and design. Many observers in the past have attempted to join features of these fields together to achieve expected synergies between the perspectives and logics of the systemic and, the sensemaking and form-giving of design. Earlier attempts at forging a relationship, a net new identity between these discourses, have generally failed to connect to the current generations of scholars and endure beyond initial forays. Mature, developed scholarship from preceding conferences was previously published in the online design journal *FORM Academic (FORM Akademisk)*, which has edited a special issue for developed symposium work since RSD2. The design journal *She Ji* published a collection of five articles developed from RSD5 (Toronto, 2016) as a theme issue[3] in late 2017. This issue follows their support for the emerging DesignX[4] discourse only 2 years prior.

[3]Jones, P. (2017). The systemic turn: Leverage for world changing. *She Ji: The Journal of Design, Economics, and Innovation, 3*(3), 157–163. https://doi.org/10.1016/j.sheji.2017.11.001

[4]Norman, D. A., & Stappers, P. J. (2016). DesignX: Complex sociotechnical systems. *She Ji: The Journal of Design, Economics, and Innovation, 1*(2), 83–106.

Significance of the Collection

As the RSD conference has grown in reach each year, the breadth of scholarly work has expanded, and the variety of interests and directions expressed by the author community has greatly increased. We believe the interstices between these highly conceptual disciplines and their creative intellectual practices afford a productive field of play for studies and practices with sufficient power to address the critical concerns of the day.

The title suggests variety across the contributions in three designations of theory, method, and practice. After continuing to read and work with the ideas in these ten chapters, it becomes clear that few papers neatly fit one category fully, or at the expense of the others. We might consider most of the chapters as integrative, as their research intent is to integrate systemics and design practice as adaptive methodologies that enable significant transformative capacity within particular wicked problem contexts. These chapters all show methodological integration, with an appropriate theoretical perspective, for collective power in various human practices.

Readers will discover a wide range of theoretical positions informing the design rationale in the reported studies and cases. For several reasons—editorial selection and the developmental progress of systemic design over several years—these analyses avoid the conventional tropes of systems thinking and complexity presented as theory, force-fit to design practice problems. Rather than drawing on systems methods or concepts for supporting observations, most of these studies show deeply integrated models and present new frameworks founded on social and/or systems theories.

The first three chapters are integrative practices and models, not pure theory or case studies but rather connecting a theoretical basis for a systemic design methodology in particular areas of practice. The collection opens with the editor's chapter *Contexts of Co-creation: Designing with System Stakeholders*. Over the last decade, we have been studying and designing collaborative practices for multistakeholder engagements in technology and organizational strategy (Jones et al., 2008), governance and policy planning, and collaborative foresight in long-horizon R&D (Weigand et al., 2013). We have collected observations and compared applications to propose effective practices for stakeholder identification and discovery, problem framing, and continuity. New contributions in the article include a review and critique of co-creation, analysed here by contexts (stages in progression) based on John Warfield's (1998) domain of science model. This model enables us to compare and transfer learning from dialogic design applications to systemic design, which is a recent discipline developing without a canon or shared standards. A new framework is proposed for stakeholder convening, transferring learning, and practice development across purposeful venues. System design and stakeholder planning projects require longer-term collaborations than provided by structured encounters such as design workshops. Therefore, a pragmatic concept defined as collaborative efficacy is proposed to assess engagement in continuous complex design situations.

Chih-Chun Chen and Nathan Crilly built a theoretical framework for integrated design, *A Framework for Complex Design: Lessons from Synthetic Biology*. Their work presents the value of an integrated design approach using synthetic biology as a learning model, reminding us that synthetic biology is itself a design-oriented practice. The chapter develops a model of designing for complexity where problems and solutions, as framed for design, are complex conditions themselves. Their proposals for systemic design practice intrigue the reader to observe, avoid, exploit, and compensate for inherent complexity in problematic contexts. They suggest both "rational" and black-box strategies for street-lighting proposals that trade off complexity features for a case problem of "designing out crime" through such interventions. Their work provides a theoretical basis for identifying and designing for characteristics in any complexity context (as they suggest swarm robotics, policy formation, and healthcare) that share similarities in complexity.

Peter Pennefather and colleagues Deborah Fels and Katie Seaborn share work from a continuing study investing electronic health records systems for health promotion for the aspiration of human flourishment. *Inclusive Systemic Design for Health System Flourishment* is a unique contribution due to the mix of disciplines and research intent, including systems biology, human factors, and information studies. Although systemic design has oriented to the ecological concept of flourishing for several years, the idea of flourishment has co-evolved as a quality of individual eudaimonic flourishing, a human phenomenon associated with psychological wellbeing, analogous to nourishment in the relationship to bioecological energy. The authors develop a link to reinforcing flourishment through registrations of human data and narratives within health records and information systems in system design. The chapter develops a framework based on social neuroscience, psychology, and inclusive human-centred design that expresses a virtuous cycle of flourishment transactions within a system of patient-centred collaborative care, in this proposal, as designed for people living with chronic pain.

Part II, Theoretical Foundations, presents four foundation studies, including resilience theory, design ethics, a systems theory of settlement, and a German cultural history of systems thinking influences and its continuing relevance to design. Wolfgang Jonas presents a "German narrative" of the history and disciplinary development of systemic design in Considerations to the Jonas title in *Systems Design Thinking: Theoretical, Methodological, and Practical*. Jonas builds on theories of first- and second-order cybernetics, complexity, and system evolution. He explores foundational systems concepts, such as irreducible complexity, the problem of control in complex systems, and the function of inquiring systems in design. Jonas proposes a scenario design methodology based on his APS (Analysis – Projection – Synthesis, Jonas, 1997) model of design and research. He positions his own work in the tradition of three precedent systems thinkers, Frederic Vester (sensitivity modelling), Jürgen Gausemeier (foresight), and Peter Schwartz (scenario analysis), leveraging scenario modelling as a design visioning process. Jonas incorporates his model and practice of Research Through Design as a core methodological framework around which the Analysis, Projection, Synthesis process is carried out. Jonas develops RTD as a design/inquiring system specifically suited for high uncertainty in complexity, building on scenarios as an analytical design method. In this way, Jonas' chapter provides a strong link between systems thinking and strategic foresight, through the projective modes of design research.

Design cyberneticist Ben Sweeting contributes to the design ethics discourse in *Wicked Problems in Design and Ethics*, a cybernetic inversion of the common normative inquiry. He reminds readers that ethics is not a settled body of knowledge or theory that we use to judge or guide design decisions in practice—that ethical inquiry is implicitly entangled with the situation, our perspectives, and our possible knowledge of options. Because ethical insight and outcomes are deeply dependent on the theories we bring to decisions and design problems, Sweeting turns this around and suggests that design may contribute as much to ethical theory as ethics to design. He explores the relationships and structural morphology between design's wicked problems and normative ethical dilemmas as a basis for proposing this symmetry. With design and ethics responsive to each other in mutual terms, ethical design questions might be released from the historical position of external limitations and trade-offs between competing priorities. Sweeting suggests the ways in which designers cope with ethical challenges in socially complex wicked problems can inform action towards complex ethical challenges in other contexts, including those within ethical discourse.

Eloise Taysom and Nathan Crilly analyse resilient systems from a design perspective in their chapter, *On the Resilience of Sociotechnical Systems*. Based on ongoing research by Taysom in Dr. Crilly's University of Cambridge lab, an analysis is developed on the differentials of resilience theory, the applications of resilience, and the possible impacts of these differentials on sociotechnical systems. Sociotechnical systems are constituted within networks of stakeholders and users, who have the most at stake in situations where the continuity and function of complex systems are tested under resilience scenarios. Deconstructing resilience as an umbrella concept, a pragmatist position is taken by drawing out the perspectives of stakeholders across numerous complex system domains. A theoretical framework is proposed addressing resilience in terms of three properties of resilience response: (a) resilience as resisting influences, (b) resilience as recovering from influences, and (c) resilience as changing to accommodate influences. Systems enabling all three responses to exogenous shock or influence can be considered to have higher capacity for resilience than systems based on one or two of the properties, as a higher variety of responses to unforeseen influences would be possible.

University of Waterloo's Perin Ruttonsha closes the section with an epic chapter, *Towards a (Socio-ecological) Science of Settlement*. Ruttonsha's analysis presents a sweeping review of urban systems thinking informed by design, culture and social sciences, and the evolution of systemic planning from the era of Doxiadis' ekistics to current complexity theory. The chapter leads with the proposal for a science of settlement (in essence, bringing Ekistics into the next century) as a study of the full complement of human–environment interactions. A comprehensive analysis of the *sustainability perspective* in urban ecology develops the locations and methods for sociomaterial intervention in the sustainment of cities in natural ecosystems. Ruttonsha further develops a phenomenological analysis of the *dwelling perspec-*

tive of human interaction in the places and experiences of habitation. The chapter closes with an analysis of the complex systems dynamics of habitation in the evolving urban form, connecting multiple theories and ideas in socio-ecological systems thinking. She connects the chapter's message to Humberto Maturana's compelling keynote at RSD5, where he challenged the conference with the many social concerns in a single question, "how do we want to live together?" The chapter aims to build a socio-ecological science of settlement, which might bridge between domains and practices in quality of life, settlement planning, and transition management.

Part III, Method and Practice, opens with Birger Sevaldson's recent development of the Gigamap as methodology. He extends the theory and practice of systemic design mapping with *Visualizing Complex Design: The Evolution of Gigamaps*. Sevaldson recounts the development of Gigamaps in systems-oriented design as an "organic" studio practice for collaborative engagement in complex system design projects. Sevaldson presents a basis for a knowledge framework for the evolution of this core methodology in systemic design. He builds upon Cross' (1999) notion of design praxiology, a philosophy of purposeful practice leading to designerly wisdom and adaptive expertise in complex systems design. Given the emphasis on "myriadic" expression, whereby system relations are expressed in their inherent complexity, Sevaldson endorses several new methods for interrogating this multiplexity that extends the sensemaking aspects of collaboration to "sense-sharing."

Silvia Barbero (Politecnico di Torino) presents studies from the Torino programme of systemic design with *Local Ruralism: Systemic Design for Economic Development*. The potential for regional economic flourishing through rural community development is demonstrated through integrated design research and ground-level projects. Her approach to social innovation aims to improve the quality of life and economic wellbeing of people, evaluating engagements with people to develop local economies in disadvantaged rural regions. Local ruralism takes into account the need to design locally supportive structures for economic and social flourishing, organically co-produced within the regions themselves. Barbero presents three significant case studies in different geographies (Mexico, Italy, and Spain) all facing declining economies. The studies develop evidence for approaches and concrete guidelines, through a systemic design framework, to facilitate systemic improvements in rural regions.

John Cassel and Susan Cousineau, collaborators in the agroecology informatics field, develop a chapter from their advancement of permaculture principles in scaling sustainable agriculture, in *Permaculture as a Systemic Design Practice*. This chapter presents the exciting possibility of relating the ecological design practices and ethics of permaculture to design and systems thinking. The permaculture movement has evolved principles for ecologically sensitive management of farming, land restoration, and the social cultivation of communities. Similar to the domain of science model (Jones' chapter), their permaculture model is extended through specific applications in an arena of practice, with lessons drawn forward into a grounded theory for general application. They suggest that systemic design can significantly enhance permaculture practices, by developing techniques for forming stable objectives, assessing appropriate technology, stakeholder engagement, and launching and managing viable agroecological projects. Building from across the systems history of permaculture sources, Cassel and Cousineau promote a framework for enabling ecological farming and management practices through designing local and distributed systems of permaculture for agriculture.

The collection that follows includes some of the most definitive and compelling ideas in systemic design, developed in an active discourse community, with peer collaboration, over the course of several years of symposia. Each of these authors discloses not only an intellectual position guided by transdisciplinary study but also their emerging practice areas of new applications that are now being tested in various stakeholder settings.

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Contents

Part I
Integrative Practices

Contexts of Co-creation: Designing with System Stakeholders

Peter Jones

Abstract The concept of co-creation includes a wide range of participatory practices for design and decision making with stakeholders and users. Generally co-creation refers to a style of design or business practice characterized by facilitated participation in orchestrated multi-stakeholder engagements, such as structured workshops and self-organizing modes of engagement. Co-creation envelopes a wide range of skilled social practices that can considerably inform and enhance the effectiveness of organizational development, collaboration, and positive group outcomes. New modes of co-creation have emerged, evolving from legacy forms of engagement such as participatory design and charrettes and newer forms such as collaboratories, generative design, sprints, and labs. Often sessions are structured by methods that recommend common steps or stages, as in design thinking workshops, and some are explicitly undirected and open. While practices abound, we find almost no research theorizing the effectiveness of these models compared to conventional structures of facilitation. As co-creation approaches have become central to systemic design, service design, and participatory design practices, a practice theory from which models might be selected and modified would offer value to practitioners and the literature. The framework that follows was evolved from and assessed by a practice theory of dialogic design. It is intended to guide the development of principles-based guidelines for co-creation practice, which might methodologically bridge the wide epistemological variances that remain unacknowledged in stakeholder co-creation practice.

Introduction

In less than a decade, the promise of participatory design as a sustained practice has diffused into mainstream practice as design co-creation. Co-creation has emerged as a normative mode of participatory engagement for design ideation, creative problem

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solving, and decision making. While contemporary practitioners may regard these practices as accepted methods, they have evolved over a 50-year period or more, from earlier forms of co-creation based on social systems and democratic practice theory. In this lengthy integration into common use, the diffusion of co-creation confirms a social form of Buxton's (2008) "long nose" of innovation, whereby new forms of practice incubate for long periods before adoption. Throughout this period, a deep foundation of knowledge and principles has been formulated, contested, and practised based on supporting research from social and systems sciences. However, we can observe that knowledge, methods, and practical applications from the originating systems practices, in particular, have not been translated to modern co-design and workshop methods. The concern for collaborative efficacy addressed here claims that normative design methods have not fully developed and remain at risk of degradation into popularized forms insufficient to the complexity of design problems purportedly addressed by co-creation.

As creative and traditional participatory design methods became popularized across a wide range of contexts, co-creation (or co-design) has emerged as a common reference to participation (Sanders & Stappers, 2008; Robertson & Simonsen, 2012). Systemic design practices have developed co-creation approaches that integrate social systems principles to guide stakeholder design for complex systems. However, emerging design schools such as systemic design, service design, and transition design offer little precedent for research support or universal guidelines for co-creation. Where systems methods cite prior scientific principles to support intervention approaches, design practices often follow "best methods" that are assumed to embody effective principles. Design co-creation methods that fail to account for social systems principles are vulnerable to systematic errors that might result in problematic consequences.

This study addresses the contexts, structures, and processes of design co-creation methods considered essential practices in systemic design. To better bridge theory across design disciplines, we include comparable practices such as design thinking workshops, stakeholder engagements, and participatory and collaborative design methods. The philosophy of co-creation, drawing on participatory design and democratic practices, assumes that stakeholders will achieve satisfactory outcomes if given responsibility for decisions and have equal status in convening roles. However, if we fail to compare these practices with other structures for engagement, we may assume or conclude that successful outcomes are causally determined by certain methods, when many rival hypotheses could explain either beneficial or unsatisfactory outcomes. If we merely valorize the perceived goodwill or social benefits of co-creation, we risk obscuring critique of co-creation methods. Our avoidance of critical discourse inhibits collective scientific learning and, pragmatically, the ability to constructively improve these methods.

Co-creation practices are highly variable in outcome, are contingent on the skills of individual practitioners, and have limitations of which their practitioners are unaware. These are similar concerns expressed in the communities of team consultants, group facilitation practices, and across all types of dialogic practices. As these practice concerns have not been addressed sufficiently in the literature, the problem of *collaborative efficacy* is introduced in this study as a concept of assessment.

What requirements can be identified for effectively adapting co-creation to match the demands of real-world complexity? Our design choices in co-creation practice must have sufficient power to anticipate and effect desired outcomes in target social systems following a design workshop.

Four current questions of co-creation practice are explored and developed:

- How can we improve our ability to understand social system contexts and to select appropriate co-creation methods to the context?
- How can we enhance collaborative efficacy in design co-creation?
- How does system context determine stakeholder representation for complex social systems?
- What systems science models might significantly enhance co-creation practice?

Background and Contexts

The practices assigned to the term co-creation are observed across several domains, and in all cases we find not a coherent methodology but a term of art encompassing many methods. As with other modes of psychosocial understanding (e.g. sensemaking), a framework for practice supported by theory would usefully inform capacities for collaborative efficacy and engagement. A framework enables the transfer of knowledge and training across different domain practices and the development of new skills upon a corpus of accepted knowledge. The intent of the current study is to propose a framework and methods, supported by an established (but relatively unknown) practice theory, to improve the capacity of organizations to advise and enact systemic design workshops with clients, users, and other stakeholders in complex engagement situations.

Both design and systems methods employ participatory stakeholder engagements, whether referred to as inquiries or interventions (in systems modes) or workshops and studios (in design). Group intervention practices based on systems theory include published processes such as Interactive Management (Warfield & Cárdenas, 1994), Appreciative Inquiry (Cooperrider et al., 2008), and Team Syntegrity (Espinosa & Harnden, 2007). Design co-creation practices are not as formally documented or developed. Numerous branded methods have been developed based on structured brainstorming and creative problem solving. Three classes of methods are frequently identified by both design and systems schools: creative problem-solving methods (Osborn, 1963; Nadler, 1981; Basadur et al., 2012), organizational development (Owen, 1987), and group deliberation processes. VanPatter and Pastor (2016) organized 63 process models into six distinct groups, all of which involve co-creation practices:

- Creative problem solving
- Design process models
- Product design
- Service design processes

- Organizational innovation
- Societal innovation

The VanPatter and Pastor report did not perform an evaluation and comparison of method efficacy; rather, they identified (mapped out) internal structures and the applicability of methods to practice contexts. No similar peer-reviewed evaluation has been published to validate the effectiveness of co-creation methods in their appropriate contexts. Many specified methods, even if claimed as scientifically based (e.g. MG Taylor and Basadur Simplexity), are branded or proprietary craft practices and therefore difficult to validate or compare. For these reasons, as well as the difficulty of mastering multiple methods, we find minimal peer critique of methods between practice communities.[1]

Branded co-creation methods are typically supported by core practice communities, trained facilitators that become associated with a single method, even if trained in many through exposure to related practices. Continuing in-cohort practice and invested expertise generally results in a kind of method allegiance, so we might argue that little motivation exists for professionals to objectively assess the effectiveness of a preferred co-creation method. Due to the absence of critical cross-evaluation or peer review of practice methodologies, we might propose that co-creation methods would be enhanced if they were evaluated and improved by assessment according to scientific or reference standard principles.

An unbiased assessment of prevailing methods would present a methodological challenge—what evaluation criteria would be deemed acceptable by the different schools of practice? How could relative levels of expertise be measured? How could the relative effectiveness between methods be presented fairly across practices without the evaluators having significant expertise in the methods themselves?

These questions are raised but not answered. The purpose of this study is to identify methodological and developmental issues shared between all co-creation methods and to recommend a common methodological solution. The assumption is made that systems theory and design methods mutually influence and enable more effective design co-creation and collaboration, and indeed that both are necessary for collaborative efficacy in stakeholder engagement. The knowledge claim is that systems science provides a basis of principles and guidance for assessing and qualifying the effectiveness of all co-creation methods.

Recreating Co-creation

A review of published practices of design co-creation reveals a scattered literature across related disciplines. Forms of structured co-creation, as a stakeholder organizing activity, are noted across disciplinary journals, from collaborative design to

[1] This observation is made based on the author's personal involvement across many group method communities of practice, from the period of research for *Handbook of Team Design* (1998) and continuing into the latest design thinking practice groups, including international online communities and conference-based communities.

design methods to dialogue workshops. The concept of co-creation has evolved independently across several broad disciplines and manifests differently in business, design, or systems fields. There is no apparent canon or core theory of co-creation that the various schools or approaches all recognize. If a widely accepted methodology is to be adopted and propagated across many practices claiming its use, it might make sense for the disciplines that promote co-creation to seek and specify a common referential basis.

Co-creation as Theory of Value

The dual distinction of "co-creation" as a design process and as a business value-finding process requires some clarification from the literature. *Value* co-creation was established as a core theoretical concept in the business literature by Prahalad and Ramaswamy (2004a). Value co-creation was proposed to encompass the shared value constructed between a service provider and consumers in their interaction with the provided service, of value in use, where value is co-created between the provider (and their constellation of resources) and consumers in interaction. In this perspective, value is not "delivered" or exchanged but co-created in active use. Prahalad raised early issues regarding value co-creation through *experience* (Prahalad & Ramaswamy, 2004b) as the basis for value realization. A radical vision for its time, they raised numerous questions only recently studied, for example, with respect to the means by which firms might engage in dialogue with consumers, the emerging governance structures for online firms with massive user bases, and the determination of appropriate management styles and methods for co-creation with customers. Several systematic reviews of value co-creation (Voorberg, Bekkers, & Tummers, 2015; Galvagno & Dalli, 2014; Frow et al., 2015) demonstrate the development of studies with empirical support for value co-creation theory, extensions, and application studies.

Co-creation is also found as a concept of value, rather than an organizing activity, in business innovation contexts. Co-creation represents the realization of value propositions in business contexts and in stakeholder engagement (Frow et al., 2015), and the concept of value co-creation is proposed by service-dominant logic (Vargo, Maglio, & Akaka, 2008). Further, Ind and Coates (2013) have connected the business theory of value co-creation to the co-creation of goods and services in collaboration between consumers and organizations. They extend the context in which co-creation occurs to the meaning-making among participants in a value constellation, including customers, designers, managers, and other stakeholders, equally. Ind and Coates suggest participatory design as a means of co-creation, but recommend no particular methods or practices.

However, many of the theoretical issues raised remain unaddressed, in particular the questions of "how" value co-creation occurs and the observed construction of the experience of value in particular domains. Prahalad's theory has been translated to the practices of design co-creation, where the formulation of new product and service propositions and artefacts are co-produced to embody the preferences and values of consumers, through key users. This leap, as it were, from theory to method might be considered one of the most influential contributions of value co-creation.

Co-creation as Design Method

In design fields, co-creation is understood as a mindset for creative participatory practice (Sanders & Stappers, 2008), with the adoption of co-creation mindsets following the diffusion of design practices into corporate and public organizations. Yet design co-creation has also been constructed as a process method in action research, as a means of facilitating stakeholder workshops in formal design. If co-creation workshops are to be used in qualitative research, a foundation of canonical work and guidelines might be expected as in any codified disciplinary practice.

The published review of design co-creation process models by VanPatter and Pastor (2016) is one of the few accounts that compare and describe factors across these models. The systems literature does not often refer to the term "co-creation," but reveals a long history of group intervention and problem structuring methods.[2] The systems studies explicate methodologies for group interventions, but do not differentiate collaborative (co-creative) versus expert-led methods. Neither design nor the systems literatures compare relative effectiveness of co-creation methods, again because there are no accepted criteria (across practices) for process or outcome evaluation.

Co-creation methodologies (or methods) are difficult to compare because they are performed in very different practice contexts. Co-creation methodologies can include modes of facilitation (e.g. Art of Hosting), creative organizing (OASIS), generative co-design, and dialogics (Open Space, Appreciative Inquiry). These practices can be rightfully defined as methodologies when structured as frameworks entailing a system of mutually coordinated methods. Yet they are frequently presented as philosophical stances and not formal methods. Even when referenced in social science studies, their phenomena and outcomes are discussed, but not their performance or measures of effectiveness with group behaviour or engagement quality. This study aims to provide a foundation for defining performance criteria and the fit of co-creation methods to appropriate contexts and effective adaptation.

In practice, facilitated or workshop methods are rarely assessed for their fit or weaknesses in a given context. The open literature may be biased by numerous practitioner studies reporting on craft workshop techniques recruited as generative design methods. There are also few scholarly articles that present cases describing applications and outcomes of more than one co-creation method. The quality criteria for this area of design practice is not guaranteed by adherence to standards or

[2] Two widely cited discussions, although not systematic reviews, include Mingers and Rosenhead (2004) and Midgley, Cavana, Brocklesby, Foote, Wood, and Ahuriri-Driscoll (2013).

evidence, or even to process criteria, but to the participants' assessment of workshop outcomes. Evaluating a final result cannot resolve the counterfactual of what a better process might have been.

Co-creation Systems

Systems approaches to co-creation are recognized by their appearance in the systems literature and their specifications of systems science principles underpinning the methods. Systems methods have been developed to support collective planning, social change, and organizational development, all atypical contexts for design practices. Systems methodologies imply their adoption of design as a process, not as a creative discipline but as an approach to synthesis in problem solving and creation of future alternatives, and to "dissolve wicked problems" through system redesign (Pourdehnad, Wilson, & Wexler, 2011). According to Pourdehnad's review, the distinctive difference between design thinking in system and design modes is the different focus of designing activity. Systems co-creation identifies stakeholders as the designers in co-creation and designers as participants invested in their future aims, plans, and outcomes—a central distinction emphasized by Christakis (Christakis & Bausch, 2006).

Systems co-creation methods are developed by formulating models, identifying systemic principles, and evaluating by continual and improving use over numerous cases. Systems methods can account for over 70 years of methodology development, as even basic workshop methods cite Lewin (1951), Mumford's ETHICS, and Trist's Search Conference. Organizational practices for large group intervention and team collaboration developed through guidance from the systems sciences, since the development of the Tavistock Search Conferences by Emery and Trist as early as 1958 (Emery & Purser, 1996), and Jungk's development of the Future Workshop in the early 1970s (Jungk & Müllert, 1987). These methods predated participatory design (i.e. Bjerknes et al. 1987) and anticipated the large group interventions now considered common practice.

Structured systems-inspired methods for collective sensemaking (co-creation) and decision making were developed following the era of normative planning and direct stakeholder engagement, as advocated by Özbekhan (1969) and Jungk in the 1960s. Following Lewin's change methodology and the Tavistock Search Conference model, early organizational change methods were directly based on social systems methodology. During a period when design workshops rarely ventured outside the immediate client context, systems thinkers Warfield and Beer were developing software algorithms to represent group decision making in emerging consensus building methods. The IBIS (Issue-Based Information System) methodology (Kunz & Rittel, 1970) was also developed during this era and adapted for collective issue analysis decades later with the Dialogue Mapping process (Conklin, 2006), an embodiment of IBIS.

The four common systems-oriented co-creation methods include Team Syntegrity (Leonard, 1996), based on Beer's methods; Appreciative Inquiry (Cooperrider & Srivastva, 1987), based on Ackoff's idealization methods; Future Search (Weisbord, 1992), based on the Emery and Trist Search Conference; and Structured Dialogic Design, based on Interactive Management (Warfield & Cárdenas, 1994). All of these share an explicit underlying principle of selection for requisite variety and/or idealization, even though each has uniquely distinct modes and other principles. Systems co-creation methods evolved from the development of scientific theory anticipating collective human behaviour. Well-developed sets of principles and methods of multi-stakeholder participation have been developed within these separate practices by peer review in discourse communities. Little work has been published relating the underlying theories to one another; as with design co-creation, practitioners of one method have not blended or integrated these forms.

Design Co-creation

Design co-creation emphasizes the collaborative, generative creative participation of individuals in design-led workshops and group practices. Sanders and Stappers (2012) describe co-creation as an evolution of participatory design practice that can be conducted by one or more of three modes: mindset, methodology, or tools for engaging users and stakeholders. Design co-creation emerged as a general approach to participatory design resulting from the broader adoption of co-creation as both method and mindset.

Searching for the sources of *design* co-creation reveals a range of commonly adapted practices, from participatory design (Muller, 2003) and IDEO's design thinking methods (Brown & Katz, 2011) to the adoption of the "unconference" derived from Open Space (Owen, 1987) as a co-creation structure.

Design co-creation draws from an ever-expanding range of creative ideational activities employed with appropriate external participants that inform generative ideation, the essential function of co-creation. The context for participation is a key differentiator in design practices. The four design domains in Fig. 1 suggest four populations of participants. Design 2.0 entails product and service design, a context in which product users are situated as the primary participants informing co-creation. Design 3.0 (organizational process) draws on the population of an organization and their knowledge and values from managers, staff, and employees. Design 4.0 draws from across stakeholder populations for social contexts of any scale—community members or citizens, for example, or members of an industry. By definition, the contexts for Design 1.0 are not indicated for co-creation. Design 1.0 involves non-complex design tasks sufficient for a designer or team under direct guidance and not directly informed by stakeholder engagement.

Since roughly 2010, the trend of increasing demand for Design 3.0 (intra-organizational) and 4.0 (social/societal) applications has driven the integration of systems-informed inquiries with design methods. After early attention towards field

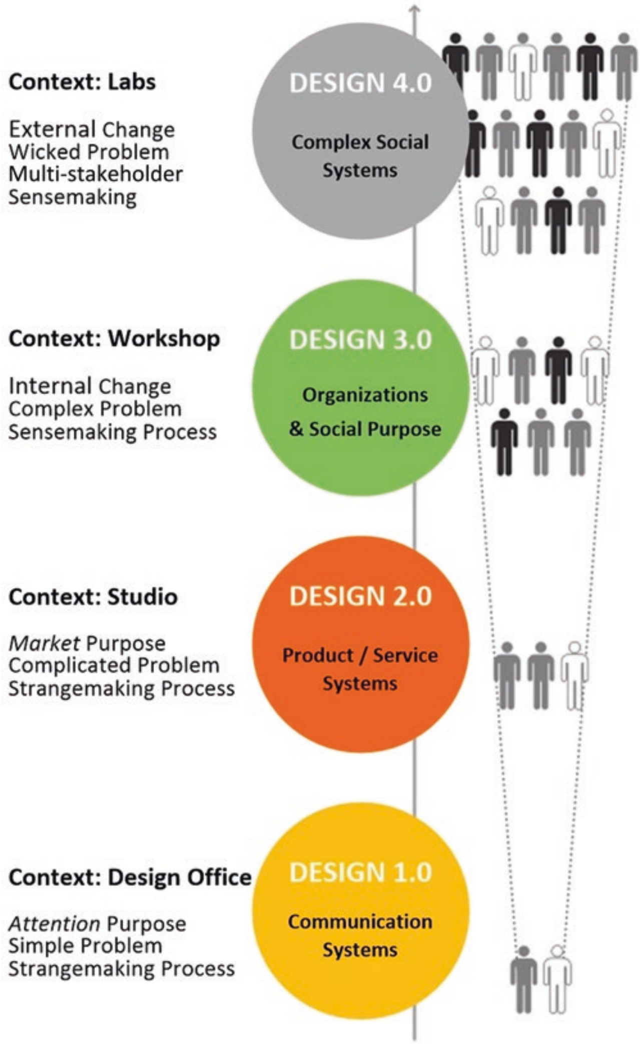

Fig. 1 Design domains and associated contexts

development of theory, methods, and cases, a current focus among scholars (as represented by other articles in this volume) has turned towards developing these contributions to improve performance in their applicable practice areas. Systemic design may be ultimately valued and recognized for field development and methodological contributions to practices and human performance in social systems.

A recent trend in design co-creation is perhaps an antithesis of systemic methodology. The "sprint" (Banfield, Lombardo, & Wax, 2015) is an emerging co-creation workshop approach that has gained use in business and public sector contexts, derived from the agile development processes now accepted and widely used in corporate practice. As its name suggests, the sprint process favours a rapid action mindset and is an intensive approach to early-stage design production and value proposals. Sprints draw on available organizational participants (Design 2.0 and 3.0) and typically proceed without user research or field studies. Sprints are similar in intent and process to joint application development (Carmel, Whitaker, & George, 1993) and Team Design (Jones, 1998) methodologies, in process and facilitation. These practices all share in common their origination as business-oriented strategies to maximize stakeholder and user responsiveness for often limited periods of team time involvement. The difference with the sprint is its emergence within a significantly different business culture than in the 1990s. JAD and Team Design aspired to become participatory practices, but such approaches remained at cultural variance to North American business organizations. The sprint process has revived the structured facilitation of these methods, with goals of high productivity and return on participation.

Among the notable trade-offs in rapid design co-creation are the lack of time for challenge reframing, the high probability of low stakeholder variety, the groupthink effect facilitated by the consensus drive to immediate accomplishment, and the brittleness of design proposals constructed in a rapid linear process. However, with the emphasis on early-stage design (initial creation) in the sprint or JAD modality, the products of these workshops are never final and are formally assessed, further developed, and evaluated by process teams following the co-creation event.

Co-creation in Design Process

While design co-creation can inform and facilitate nearly any collaboration, it emerges as necessary in complex domains for which a design team would not have knowledge or agency. In earlier work (Jones, 2014), we illustrated four domains that define contexts for design team, participation, and venue for design activities. Figure 1 presents this scaled model differentiating relationships that facilitate the focus of design attention to sensemaking (understanding and articulating stakeholder concerns for design decision), change-making (orienting design decisions towards social or organizational change), or “strangemaking” (articulating design products as distinctive means of shaping attention, as in design of brand identity). The venues—Studio, Workshop, Office, or Lab—reflect four currently practised applications. The framework developed further in the article proposes new distinctions for these venues as contexts aligned to design purposes.

Design 1.0—*Design Office or Studio*. Simple design problems, well defined by briefs. A small design team working within a team context, guided by project sponsors and a design brief.

A “strangemaking” context where the typical object of design is to produce a distinctive, original artefact perceived as unique and high quality.

Design 2.0—*Design Studio*. Complicated but not organizationally complex design problems, resolvable through contemporary methods. A multidisciplinary design team in service to sponsors (product/service owners), typically using an iterative design process in a studio environment.

Balance of sensemaking (e.g. the consensus of understanding developed from user research) and strangemaking (the unique offering and position of product in a market).

Design 3.0—*Design Workshops*, usually at sponsor locations. Complex organizational problems, which may appear complicated until differences in stakeholder positions are recognized. Contexts are not knowable to external design firms, and conventional methods may be inadequate to the complexity of power, history, and routines in an organization. Design team plus multiple expertise disciplines in stakeholder workshops within an organizational setting.

Sensemaking context, with object of design to reach understanding and facilitate decisions for value co-creation for the organization itself, rather than markets. Yet the problem space remains complex and sensitive to the overdetermination of methods.

Design 4.0—*Design "Labs"* hosted by third-party mediators for multi-organizational workshops. Complex problem space that is identified as an external situation of concern to the stakeholders, such as climate change or affordable housing. Sponsors may be a supra-organization, but the multi-stakeholder context may call for offsite or "neutral" locations for workshops.

The object of design may be a strategy, policy agreement, operational concepts, or plans developed by parties in sensemaking context. Methods are entirely oriented towards sensemaking and achieving shared understanding for mutual action.

A default context for formative design co-creation assumes a workshop setting with client and/or user participants joining an extended design team. The physical venue might be a large, supplied conference room or a studio room in the design office.

These venues or settings represent genres or habitual modes of practice developed through accommodation to increasing organizational adoption. As venue and process structures have become less formal through greater adoption of co-creation activities, a wider range of creative and participatory methods have been drawn in to facilitate collaborative ideation and creative visioning and planning. Informal design practices appear to demand less organizational investment. With greater acceptance of informal design-led modes, the demand for more formalized, validated methods has declined, due to the comparative time and costs involved in managing highly structured process. As sponsors have become conversant in the genre of structured collaboration workshops and relax concerns for their productive output, increased demand has emerged for shorter engagements, faster turnaround, and immediate deliverables from co-creation activities. A framework for systemic design co-creation is proposed to enable designers to balance these economic and organizational demands with the necessary activities that guarantee quality outcomes and collaborative efficacy.

Co-creation and Co-design

Design co-creation workshops have experimented with mixes of systems practices and design methods in various ways. A common approach is to develop systems thinking models for understanding contexts and relationships in *existing* problems, and design thinking as methodology to create formative or future possibilities. Typical methods present a system as an existing complex situation that requires inquiry to achieve a common understanding of patterns, behaviours, and places for intervention. Interventions are designed as future options for change in the existing system.

Co-creation approaches, whether as mindset or method, have become adopted as design thinking methodologies across corporate and public sectors (Ind & Coates, 2013). Due as much to their accessibility as effectiveness, design thinking methods have expanded into government and social services and increasingly policy and governance. Fred Collopy argues that, because systems thinking failed to demonstrate wide adoption in management practice, design thinking offers a potentially more productive approach for managers and organizations to engage in complex problems (Collopy, 2009). His argument recognizes the lack of system dynamics reasoning by managers, after more than a decade of training and promotion in business education (Senge, 1990). Collopy proposes that the iterative, product-oriented creative tools of design thinking readily align to the project-oriented work practices of contemporary organizations.[3] While design thinking has now become a broadly adopted approach, its influence in management practice has still not been established, even after a decade of curricular promotion similar in many ways to the systems movement. In co-creation practice, the envisioned integration of thinking methodologies might be developed or fused in the enacted practices of managing projects and multi-stakeholder production.

Co-creation in Social Systems

In the complex, non-parametric (and indefinite outcome) design contexts of Designs 3.0 and 4.0, collaboration among decision makers, experts, and stakeholders becomes a requisite to facilitate agreements and mitigate risks of foresight and execution uncertainty. These contexts for co-creation are complex social systems, involving design and decision processes for large organizations, public sector institutions, industry consortia, healthcare systems, and similar organizations. Complex contexts differ from the problem framing orientation of design, where the shared goal might be to optimize a product or service proposition. Co-creation within

[3] Jones (2009) joined this argument by suggesting that systems thinking was not widely adopted because it failed to address the everyday coping practices of managers, not that it failed as a reasoning mode per se. This proposal suggests a blend of systems thinking with design tools might better resolve complex concerns in innovation contexts.

social systems requires dialogue to elicit, understand, and contrast perspectives and positions, as only dialogue is able to resolve the "variety" in the system context of interest. Both Christakis and Beer argued that forms of dialogue are necessary for channelling and satisfying the requisite variety in a complex social system. Co-creation can be understood as a variety transformer, which accepts the high variety of inputs in a problem system and guides the resolution of positions to a preferred, commonly held reduction of variety into agreements and design decisions.

A substantial body of knowledge on dialogue science exists that might inform co-creation methodology. However, while some models of dialogue are situated in complex organizational settings (e.g. Isaacs, 1993), there is no consensus regarding dialogue methods in design co-creation. It seems likely that systemic design practices could be significantly enhanced by the disciplined exploration of dialogic methods in social systems applications.

A further critical observation is that the micro-practices of dialogue, which require extensive inquiry and sufficient time for listening to all positions, may be at odds with the action-biased approaches of generative design co-creation. From critical observations, it also appears that the time demands for dialogue constrain the practices and therefore choices in design co-creation. An argument can be made that these are false limitations driven more by expediency and the increasing demand for time-efficient practices. The integration of dialogue in design co-creation has not been sufficiently evaluated in real applications to address these superficial assessments.

Framework Development

The effective transfer of learning from a situated methodology to a new domain requires a clear definition of principles and options known in practice and from cases. This study applies the methodology of dialogic design to design co-creation. It follows scientific principles from Warfield's (1986) Domain of Science Model (DoSM) and models extending the DoSM (Christakis & Bausch, 2006; Christakis & Dye, 2008). Warfield promoted the DoSM as a methodology for improving and sustaining a methodological practice, which could include a discipline or design process, following a rigorous process of self-observation, evaluation, and adaptation over the cycles of practice. Without intentional evolution of a methodology, codified processes can drift from the original practice and erode or disappear if not renewed by continuing application and assessment. As Warfield did not publish the DoSM, its working paper became used as a reference model for practitioners, as a kind of practice theory guiding the advancement of systems methods. To our knowledge it has never been applied outside the systems sciences, so the application to design science in the current research represents an "extension.[4]"

[4] The DoSM is *extended* (in the mathematical sense of a logical continuation of a set) to construct a reference model of the performance of collective design practices, commensurate with science and practice.

The DoSM was designed as a practice framework first applied to generic design science (Warfield, 1994), a framework for sociotechnical systems design. Warfield attempted to establish a rigorous basis for describing and intervening in human complexity based on process principles, an approach at odds with the emergence of complexity science at the time. Generic design science is based on structured methods, the formulation of stakeholder observations, and the use of mathematical formalisms to facilitate inter-observer understanding of systemic relations. He formulated two general laws of practice extended to the DoSM:

- Law of limits (all human activities have constraining limitations that must be observed for effective action)
- Law of gradation (conceptual developments, such as in science and design, are structured in stages of progression)

A series of design principles (laws of practice) were drawn from generic design science, which Christakis further developed in the dialogic design science (Christakis & Bausch, 2006; Bausch & Flanagan, 2013). The DoSM requires a corpus of codified knowledge and formal observations to propose extensions to a methodology, constructed from axioms (first principles) as a reference model. This framework was applied to the evolution of Structured Dialogic Design (SDD), the primary practice associated with DoSM. SDD methodology satisfies both laws of practice in the DoSM. SDD is founded on a careful match of methods to human limits, to accommodate the real limitations of cognitive bias, groupthink, and power relations within individual and collective performance. The extension of the staged model promotes continuous enhancement to accommodate changing ecologies of application. Stage gradation enables the transfer of scientific foundations, extending knowledge from dialogic design (a systemic design methodology) to the design practices of co-creation.

Application to Dialogic Design Practice

While the theories of Warfield have been advanced into practice by Christakis, there are core "Warfieldian" theories that might help bridge systems design practice. Systemic design can be conceived as optimizing processes for group design and decision making under conditions of overwhelming conceptual complexity. Based on Warfield's theory of complexity, we address the insufficiency of any individual (or conventional meeting) to resolve relevant knowledge and identify enabling distinctions to make decisions commensurate to the emergent social complexity of a future-situated problem system. Interactive Management was originally designed to enable groups to formulate high-quality conceptualizations of problematics and to achieve durable collective decisions with consensus based on an understanding of systemic relationships.

The process entails high-quality observations from the requisite stakeholders in a system to reach consensus through deep (or sufficient) conceptualization to enable effective design decisions and change proposals. Such a description of process and outcome was at the heart of the DoSM and the dialogic design processes derived from the model. Warfield and Christakis described the insight within this staged process model as "lessons of the Arena."

While Warfield did not publish a methodology for applying the DoSM, Christakis adopted the framework to inform the evolution of dialogic design science (Christakis & Flangan, 2011). Dialogic design extended the earlier practices of Interactive Management with a systems science foundation to enable its extension by the community of practitioners. This process was initiated by the first compilation of methods and cases (Christakis & Bausch, 2006) and then developed by continuing deliberations, resulting in a series of publications and a revised methodology denoted as Structured Dialogic Design (SDD).

Christakis, collaborating with the practice community, articulated a coherent practice theory and principles that enabled a complete systems thinking process for democratic, collective decision making drawing on the emergent wisdom of participants. Essentially, the original process (based on IM) was rigorously analysed by practitioners for its insufficiencies to democratic theory. Using the DoSM as a guidance, principles (e.g. axioms and laws) were assessed to inform a complete methodology that would serve the applicable practice contexts in the community. We can now make the case that through this self-assessment process, dialogic design functions as a meta-methodology, providing a process framework that can support and validate a wide range of design practices.

A Process for Advancing Science as Reflective Practice

Warfield argued that "higher-quality language" had more impact on science than hypothesis testing, an extraordinary claim and one underdeveloped in science studies. His argument draws on the observation that scientific knowledge advances based on the collective understanding of concepts in a language domain. Higher-quality language enables the effectivity of understanding and the construction of more convincing arguments, allowing scientists (and practitioners) to release strongly held positions that would prevent the adoption of productive principles and methods.

By extension, the same claim can be made for other disciplines, including engineering, design, and certainly social sciences (wherein theoretical positions completely unsupported by hypothesis testing are commonly sustained in the literature). A disciplinary (science or design) language can be clarified through dialogue practices, and very probably similar dialogic practices can facilitate language clarification in any discourse. However, dialogue to produce meaning shared across discourses has become essential for complex systems design, which might involve designers, engineers, scientists, and decision makers. Krippendorf (2000) claims "*languaging matters* enormously."

> Discourses construct vastly different realities into which the ideas of a discourse are inscribed and in turn become available for inquiry and elaboration. … Different discourses not only construct incommensurable realities, their pursuit of different paradigms yields different kinds of knowledge: Experiments are not treatments, and neither are technical inventions (p. 56).

Krippendorff (2000) points out the futility of attempting to harmonize languages between discourses, as this has the effect of reducing the quality or accessibility of meaning to those within the relevant discourse of interest (e.g. design). According to Warfield, the effect of "universal priors" in a discourse based on commonly held knowledge prevents the advancement of high-quality hypotheses (in sciences) and, by extension, design proposals. A new language paradigm would be vastly more productive than sustaining a legacy language that unreflexively held embedded values and positions. However, even as emerging high-quality observations become validated, pre-existing languages and paradigms can persist well beyond their utility in the emerging knowledge base.

Warfield proposed several guidelines that address the research questions of this study, including context of action, stakeholder selection, and validating (selecting) methodology. His guidance included dictums to use design practices to develop a basis for a human science that accounted for whole persons in intentional design and decision activities.

> Conversely, the best way to validate a Science is to manage the language through careful design practices, and to incorporate the Theory of Relations and its isomorphisms as part of the Foundations of the Science. (Warfield, 1986, p. 10)

His recommended process for managing the language of a discipline was a rigorous catalogue of definitions and distinctions for applications. The DoSM proposal was a call for defining the boundaries and *concepts* that constituted a discourse. Warfield believed the means of testing the effectiveness of a design science was to perform its functions in an application with stakeholders (in an *Arena*) and then assess the results in reference to principles established in the theory base (the *Corpus*). He indicated in several papers that a similar methodology for consensus language construction was applicable in organizational (Warfield, 1999) and stakeholder domains (Warfield, 2007). These proposals allow the current study to bridge this model from scientific disciplinary contexts to systemic design practice.

DoSM Model and Design

We also aim to bridge Warfield's DoSM functional model to design methodology. The basic model of the DoSM is shown in Fig. 2, a staged cycle of processes in a series from Foundation to Theory, to Methodology, to Applications, and then to Foundation.

The DoSM represents an idealized process of iterative development of a discourse and practice. The model represents a deliberative process that practice members follow by anticipating the application of methodology to an evolving range of problems. For dialogic design science (and practice), the DoSM has been followed

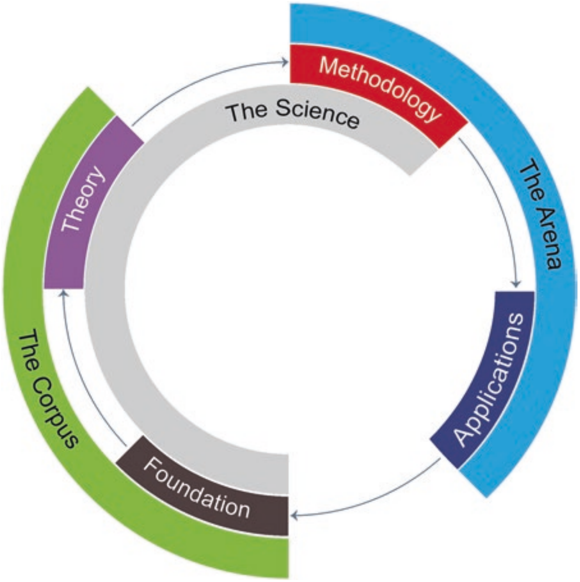

Fig. 2 Domain of Science Model (From Warfield, 1986, image courtesy of Jeff Diedrich)

through (at least partially) four "learning iterations" by the community of practice associated with the research.[5] The staged cycle was envisioned as developmental, wherein learning from research in each stage (*literations*) would yield insights informing the successive stage.

The DoSM entails four stages in two contexts, the Corpus and the Arena, and four linkages of translation between them. The Corpus consists of a Foundation—the prior relevant body of knowledge in a discourse—and Theory. Theory represents the generative extension of the Corpus with descriptive and normative propositions that enable new methods and practices to be developed.

The Arena is the primary context for practice, the application of methodology with stakeholders in a field setting. Methodology refers to the integration of methods in a validated framework, in this case Structured Dialogic Design (SDD). The Application refers to performance of SDD (or theoretically any methodology) in the context of a stakeholder "arena."

This separation of contexts from purposes applies to other practices such as design. As in SDD, it will be unproductive to reinvent every engagement in an Arena; in fact, the impulse to innovate can introduce and transfer risk uncertainties to stakeholders. The DoSM represents a meta-process however, not a theory of change or even of learning from a given engagement. By visiting a stage in reflec-

[5] Institute for 21st Century Agoras, the non-profit organization established to sustain SDD practice and studies with the social purpose of democratic transformation through structured dialogue

tive practice, a learning reflection transfers information and outcomes from that stage to inform the next. These stage transitions can be summarized as follows:

Foundation to Theory This transition translates knowledge in the form of postulates, or axiomatic proposals that inform theory. New references and practice models assessed from applications will be documented as foundations. In the Agoras case, the number of axioms proposed for use in SDD methodology expanded from four to six in the first cycle (2006) and to seven in a second revision of axioms (2009). New laws (principles) were also proposed and evaluated over this DoSM cycle.[6]

Theory to Methodology Selection criteria are translated to methodology, enabling selection of methods in a coherent framework. In practice this includes criteria for proposals or enhancements to a methodology based on theoretical principles. In the Agoras case, criteria for methods were proposed for virtual SDD engagement (2006). Revisions to the theory base and methodology have also been developed in the literature by Agoras members.

Methodology to Application Warfield suggested changes to roles and environment, but revisions to applied practice often emerge from methodological innovation. In several publications and related engagements, Jones (2014, and with Weigand, Flanagan, Dye, & Jones, 2014) demonstrated the application of novel methods for thematic discovery, stakeholder selection, and hybrid design practices.

Application to Foundation The feedback from the field to inform research remains a weak link in most disciplines. Theorizing lessons from practice has been fraught with lack of breadth (across practitioners) and closure (completeness of measures or balance). Warfield only specifies feedback as "strengths and weaknesses," a review point that might start a new cycle.

The current study sought to apply lessons from the DoSM in dialogic design science to applications in systemic design, a practice area that has developed through design education (Jones, 2015) and reflective inquiry (Nelson & Stolterman, 2012). The DoSM can be extended to propose evolution of systemic design, drawing on dialogic design to inform the emerging constellation of systemic design applications. Systemic design applications typically refer to arenas in the Design 4.0 scale such as ecological concerns, urban design, health, and other policy or social systems that require multiple stakeholders.

Translation to Collective Design Contexts

The staged model of the DoSM from dialogic design science is translated as a model of development for co-creation practice in systemic design. The original language of the DoSM is maintained for consistent reference to the mode.

[6] The seven axioms (and laws of dialogue) are significant in themselves as design propositions for dialogic co-creation and are presented in the Framework section.

The basis for the proposed DoSM draws from over a period of 10 years of observation in the arena of primarily public sector projects, as well as analysis of cases from the community of practice. The general process of four stages from Foundation to Theory, Methodology, and Application is retained. The venues of prior (formative) contexts reflect current co-creation practice as evidenced across numerous cases.

Adapting the DoSM to design co-creation required a significant change to the stage contexts. More recent practices and studies have defined the "Arena" as a type of practice setting, a private convening context identified by its stakeholders and their matters of concern. The context of the Agora for stakeholder design was developed by Christakis as a reference to the open public context congruent with the Athenian agora, defined by its accessibility to publics. The Agora discloses a democratic, participatory context articulated by its availability to public stakeholders. Where participants may be invited to an Agora, the context of the Agora represents an accessible venue available to interested members of society. An Agora is defined by the context that the public extends to the venue and its dialogue, rather than by the topic or issues defined by the conveners.

The Arena encloses a selected body of stakeholders representing external potentials for action. There are two types of arenas that occur together in practice. One is the venue of a multi-stakeholder engagement that attempts to formulate a microcosm of the actual social worlds of action in which the stakeholders participate. The other is the sociopolitical idea of arena, defined by Mintzberg (1985) and later Renn (1993) as the organizational context of decision actions by which problems are framed as significant, risks are identified, and resources are allocated. Both of these are implied in the arena of co-creation.

The DoSM for design co-creation is presented as a reference model from the domain of science to anticipate and formulate design functions in four stages. Numerous case studies can be assigned to support and define appropriate practices within each stage. Unlike the DoSM, the contexts do not match each stage precisely, a boundary quandary indicated in Fig. 3. Two contexts (Arena and Agora) are both Applications. Foundation and Theory can be assigned to the Lab. The Studio extends the design of Methodology from the Lab.

Extending the four stages of the DoSM are four contexts of the Lab, Studio, Arena, and Agora. These are observed to match the arrangements of each context for the purposes of co-creation and specific forms of group sensemaking in each stage.

Lab The Lab provides a venue for internal research and deep analysis, theory building, and creating new artefacts to evaluate in a studio setting. The Lab represents the most focused venue and smallest number of organizational participants, and would not typically engage managers and decision makers. Consistent with scientific laboratories, the social and design lab provides the most value as a venue for internal development of systems design proposals, formulation of engagement approaches and methodology, and rigorous evaluation of design options.

In systemic co-creation practices, members can collaborate on creative proposals drawing from the sources in the Foundation. As a task of corpus development, the

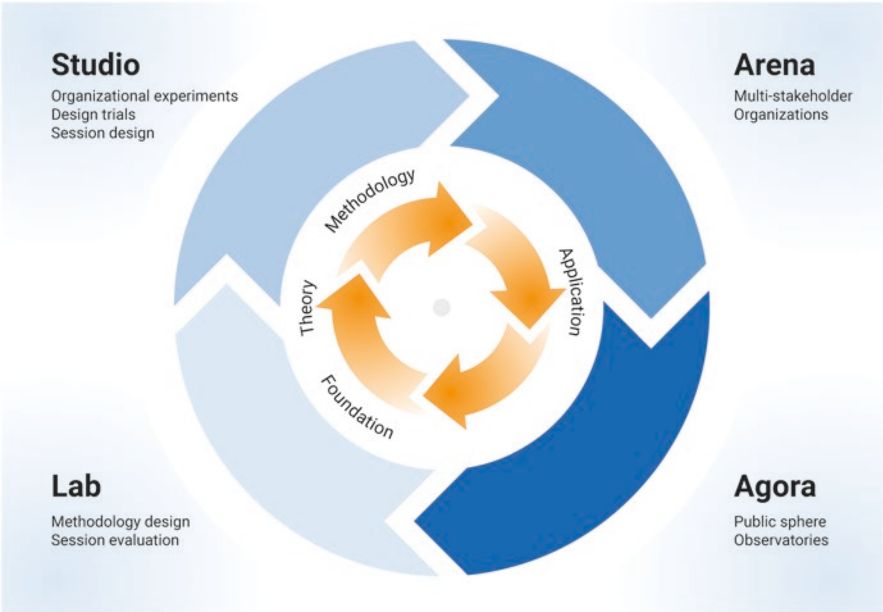

Fig. 3 Stages of DoSM in co-creation contexts

Lab activities draw from across applicable sciences and knowledges (design, systems and cybernetics, philosophy, social sciences, engineering, economics). Sensemaking activities consist largely of problem understanding and framing, including social research, and identifying external references and stakeholders appropriate to defining and advancing methodology.

Studio The Studio represents an internal venue for collaborative design activities conducted to develop concepts, proposals, or prototypes. The Studio is appropriately named based on generations of design education and client work conducted in studio contexts. As the Lab is a strictly "experimental" and developmental context, the Studio provides a place for members to productively collaborate on defined projects in nascent form. The Studio facilitates sociomaterial activities of constructive making. It perhaps is better defined by its composition than its physical environment, as it is one where a core design team invites multidisciplinary collaboration with relevant experts, process advisors, and technical masters.

As suggested by Fig. 3, the Studio (in the context of the DoSM) affords team members the appropriate place to select and develop methodology planned for specific engagements in the Arena. The Studio can be a temporary zone used by team members, client representatives, and invited experts to construct and evaluate plans and engagements. Revisions to methodology, prototype models, and trial sessions can be constructed and evaluated by the team in advance of Arena engagements.

Sensemaking activities in the Studio comprise largely of problem understanding and framing.

Arena Christakis and Warfield defined the Arena as the venue for engaging stakeholders representing the requisite variety of a social system in issues of their direct concern. An “Arena” (Renn, 1993) may be understood as a symbolic location of political action that influences collective decisions. Rather than a specific organizational or policy context, it implies the sociopolitical environment of design process or decision making for outcomes of interest to the selected stakeholders.

Stakeholders are not participants because of their beliefs or even expertise, but based on their capacity to take action and motivate others towards preferred outcomes. The requisite variety of a social system almost guarantees that stakeholder positions, power, and motivations will reveal conflicts or be at odds. The appropriate methodology for negotiating the structural and emergent complexity of the Arena is dialogue—design “qua design” is insufficient to address power variances, and the anticipation of arena constituents requires sufficient methodology and dialogue management capacity.

Unlike the Studio, the Arena context is strictly facilitated; collaboration is structured to prevent inequitable decision or unbalanced coalition formation that might offset perception of the possibility of a consensus outcome across all participants. Arenas are often held in neutral locations with the ability to specify and control the environment. If a large “design studio” environment is used for smaller stakeholder meetings, there may be symbolic meaning to stakeholders.

An Arena differs from the other venues in that only committed stakeholders are invited. A salient process management concern is to facilitate a fair and productive environment with respect to decision power and appropriate stakeholder variety. The Arena constitutes a context for direct application of methodology for the benefit of participants.

Agora The Agora extends the model of design co-creation to democratic contexts, by restoring the committed citizen stakeholder as central to a public. The Agora is not necessarily a venue or place. An Agora shows up when members of a public participate in purposeful dialogue or congregate to co-create and act on a social position. The Agora extends the domain of Applications from Arena to the open public sphere, which becomes enframed for an issue or purpose through disciplined dialogue.

The Agora differs from other stages in the DoSM cycle in that the Arena does not expand or extend to form or inform an Agora. It extends the DoSM however as it establishes a new domain of application praxis informed by prior science and methodology learned in Arenas over time. The Agora holds the potential for significant development of public power and influence, beyond that of the Arena’s typical collective problem-solving orientation.

Systemic Design Framework

There are several hundred publications of studies and significant cases demonstrating the effectiveness of SDD and (over 20 years ago) Interactive Management. Most of the methodological development and experimentation remains unpublished, following the tradition in sciences of only reporting peer-reviewed findings and outcomes. The current study builds on the foundation of Flanagan's development with Christakis (Christakis & Flanagan, 2011) and with Bausch (Bausch & Flanagan, 2013) of the major components of a corpus for the SDD methodology. I extend the DoSM to co-creation in systems design practices developed respectfully on the collaborative scholarship of this discourse community.

As in any scientific development, the history of progress is reported through snapshots of research output. The long cycles of developmental work are rarely reported. In the research group associated with the research,[7] the DoSM cycle has been advanced within three cycles of development and up to four partial cycles, since 1997. The major cycles of development are represented by formulation of new Foundation concepts, revisions to Methodology and evaluated trials, and enhancements to practice in the Arena. Observations are presented in summary, incorporating by synthesis the results of research tasks in each cycle.

Process of Model Development

Evaluation and design within the DoSM cycle followed a design-oriented action research process, with a basic series of problem framing, data collection, assessment and analysis, and reflection on findings. Internal sessions as well as full client workshops (applications) were documented and analysed for stakeholder outcomes and methodological effectiveness. Plans, trials, and analyses were also documented throughout the process.

The purpose of the DoSM is to provide guidance for the disciplined cooperative development of a "science" or a body of first principles and methodologies accepted as a working body of knowledge in a practice. The power of a scientific mode of knowledge production, whether for a research discipline or a methodology such as SDD, is that learning and improvements to the practice can be validated and generalized. The "science" at minimum contains the body of knowledge and the rules (methods) for exploiting the knowledge for productive human ends. Without conducting practice research, the innovations developed by practitioners in the Arena can be lost or remain invalidated "personal" styles of facilitation. If we fail to evaluate the effectiveness of new theoretical propositions, the discipline risks slipping into a craft practice. This slippage between a proposed methodology and its performance in the Arena remains a common drift observed in design practice.

[7] Institute for 21st Century Agoras is a non-profit organization established by Alexander Christakis and a core group of senior practitioners and scholars dedicated to the development of democratic practices based on dialogic design science.

The objectives of the 5-year period of practice-based design action research were to identify and respond to salient gaps in the practice, improve and adapt dialogic design methodology to the emerging discipline of systemic design, and thereby redirect the DoSM to a novel design context. The study did not originally envision changes to the modes of co-creation, yet the analysis revealed this opportunity and expressed the following findings, most of which require further research or theorizing.

1. **Adapt Co-creation Methods to Contexts**
   Design co-creation approaches in most design practice are largely based on the Studio model (informal small-group workshops) and one-off large-group Arena workshops. Due to the popular framing of organizational innovation "labs," no distinction is made between activity types suitable for different contexts, as nearly any project context can be represented as a "lab" in current practices. To expand the strategic options available to design practice, consideration ought to be given to the DoSM distinctions that define meaningful contexts for different design activities, participants, and outcomes. Therefore, a definitive lexicon of co-creation frames is proposed.

2. **Design Thinking Co-creation Is Insufficient for Complex Systems**
   Conventional design-led approaches can be shown as insufficient and too short-sighted for the complexity of Design 3.0/4.0 problems. Workshops often rely on popular methods for user understanding such as empathy mapping, idea generation based on small-group brainstorming, and concept formation based on randomized small-group co-construction. These may result in the creative satisfaction of an enjoyable learning experience, but often yield little or no commitment to development or insight into systemic issues in a complex situation. Design thinking's reliance on rapid co-creation methods may offset the effective adoption of structured or staged design methods. Typical design thinking approaches advocate generative creativity to maximize ideational productivity (e.g. "generating more ideas leads to more of better quality"). Continuing reliance on popular modes of design co-creation can erode the potential for structured, rigorous, or systemic approaches that require significantly more investment from participants and sponsors. Design professionals are responsible for enriching the vocabulary and methodological variety available to clients and collaborative projects.

3. **Effective Co-creation Requires Continuity of Consultation**
   Co-creation workshop events require significant support and planning if they are to offer stakeholders more than just facilitated design ideation. Planning and follow-up engagements are often neglected in the design management process, as the skills and objectives for *continuous* episodes of work differ from those in stakeholder *engagement* events. Long-duration, continuous engagements (over a year) require consultation for sponsors and their stakeholders to develop a capacity for effective design and action. The DoSM accommodates an extended cycle by introducing skills and management in the Studio context, in advance of Arena engagements.

4. **Adaptive, Staged Planning for Successful Co-creation**
   For Arena contexts with committed participants, a significant period of inquiry becomes necessary in advance of design co-creation, or the engagement risks an incomplete apprehension of problematics and may suffer from insufficient dialogue towards consensus. Studio workshop practices can be employed to frame focus questions and materials to aid stakeholder understanding in successive Arena engagements.

5. **Stakeholder Accommodation Conflicts Managed by Context**
   Longer-duration consultations may be necessary for long-term productive outcomes, consistent with the time required to enable organizational learning cycles. In many arenas, we can report that stakeholders demand radically shorter time periods per discrete session. An ever-increasing observation among SDD practitioners is that our stakeholders (not necessarily sponsors) are unable to invest 2–3 days duration for mixed-participant co-creation sessions. Workshops of just a single day or less have become more common. We can observe a change in co-creation practices (and method) as design teams continue to accommodate stakeholders by reducing the engagement life cycle to timeframes managed by sponsors. Stakeholders (mixed participants) invited to sponsored co-creation sessions in an Arena often require shorter, focused sessions supportive of their decreasing accessibility. Structured co-creation is required to facilitate sufficiently productive results from these constrained performance timeframes.

6. **Insufficient Stakeholder Discovery Risks Variety Deficit**
   A significant weakness in design co-creation is insufficient attention to stakeholder variety and discovery, by relying on immediate, interested, and available participants without carefully determining requisite sampling variety necessary to fully inform the scope of an inquiry. A critical enhancement to (Arena) practice in this study is a formulation of rigorous stakeholder selection and analysis methods that support requisite variety in stakeholder discovery and associated thematic development of triggering questions.

7. **Methodological Research to Improve Mixed-Presence Co-creation**
   With broad collaborations across geographies and increasing experience with teleconference services, we find an increasing desire for effective mixed-presence co-creation. The employment of mixed-presence modes for SDD and Interpretive Structural Modelling (ISM) in collocated and remote Arena sessions remains underdeveloped and lacks validation in the literature. Significant progress has been made in recent software platforms for creative co-creation. The specialized software systems for SDD (including ISM algorithm development) are now web-hosted and improved.[8] Emerging web-based software platforms and

[8] The primary software systems for SDD include Cogniscope 3 and logosofia. Emerging platforms such as Idea Prism (Future Worlds Centre) are being developed for large-scale remote participation. The Interpretive Structural Modelling algorithm is technically a public domain routine but is developed and maintained within the practice communities that use it regularly, inclusive of the development teams for the SDD software.

videoconferencing have not been validated in methodology (Lab), trials (Studio), nor Arena applications.

These seven observations summarize several fundamental and recurrent problems in co-creation practice. They are not reported in the literature, perhaps due to the inability to openly observe or assess methods in practice research and the relative lack of practice validation studies. Co-creation has been treated as a proprietary craft practice, similar to other design methodologies in wide use (e.g. Open IDEO[9]) that are also unreported in scholarly studies. Design co-creation is not yet treated as a scientific domain that encourages replication and serious external contributions. For co-creation to be determined as "systemic" however, some degree of criteria and tests might be considered that could demonstrate how intended system-level outcomes can be achieved productively. A systemic design methodology ought to also foresee and resolve problematic organizational, social, and psychological constants affecting group sensemaking.

Co-creation System Model

We propose a general model for co-creation practices across contexts, synthesizing from the findings of DoSM research for two practice areas, dialogic design and systemic design. Figure 4 presents the four stages based on the DoSM indicating the customary contexts for co-creation in design practices.

Co-creation in design practice cannot be formalized as a scientific canon; we can instead promote a disciplined attempt to generalize known principles as a model for further development.

While the Corpus/Application model derived for scientific development could be retained, the contexts for design have been represented appropriately to support current practices. As four "venues" these are associated with four domains of design activity in systemic design contexts:

1. **Lab**—*Academic and Experimental*. A Lab context is a private, exploratory venue for core design teams to develop concepts and methods. A Lab provides a safe-to-fail methodological testbed for formulating proposals and conducting individual and small-group design activity. Core design research teams require a dedicated venue, free from sponsor or project involvement, to be a proper "laboratory." With the conflation of the term "labs" now associated with all types of design workshops, the notion of a lab as a private working space for internal teams may be eroding.
2. **Studio**—*Design-Led Exploration*. The Studio environment provides a collaborative setting for all team members to work together on projects in active

[9] Open IDEO (openideo.com) provides resources for design thinking and co-creation in member-led design challenges, most of which are public sector or community value projects, attesting to the "open" reference in the organization.

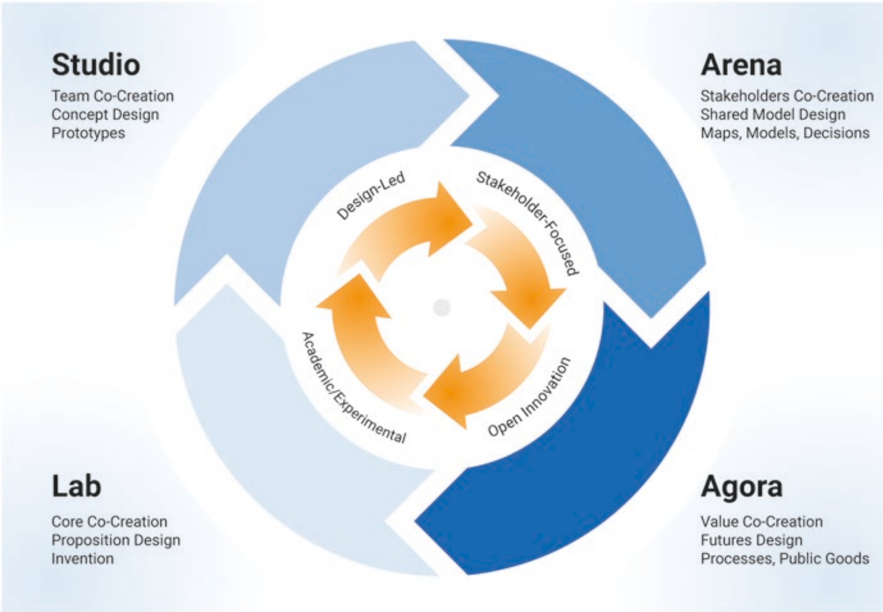

Fig. 4 Adapting the DoSM to co-creation contexts

co-creation and development. In design practice there is a continuous need to convene small groups for concept development, workshop preparation, prototyping, and methodological design. Engaging sponsor team members in studio sessions, design will follow a cycle of workshop encounters and preparation episodes.

3. **Arena**—*Stakeholder-Focused* (private context). The Arena represents the venue for engagement of committed participants in co-creation in dialogue and decision making. The Arena provides the context for applications that co-produce enduring value (beyond the session itself) for both participating stakeholders and those represented by invited members. The Arena is the only context in the cycle where we identify "stakeholders" as participants, as the Agora involves citizens and the Studio engages team members, not stakeholders.
4. **Agora**—*Open Innovation* (public context). The Agora provides an open-ended context for engagement of citizens and publics as participants in co-creation through inquiry and futures creation, according to their own self-determination. Co-creation in the Agora typically engages topical concerns of known public interest, but the level of investment (commitment) to action or design may be inchoate, requiring further staging of engagements to create coalitions for action or dedicated communities of inquiry for an issue.

Three system functions have been identified for each context to define associated practices.

- *Co-creation structure*—The design team and participants in the context (Each context is expansive to potential containing social systems: Core, Team, Stakeholder, Value (public or market).)
- *Design function and process*—The purposeful function of that context and essential process
- *Outcome of design co-creation*—The artefacts or form of design output from the co-creation process

Table 1 presents a function mapping of the design process and products for the four contexts, describing the DoSM diagram in Fig. 1.

The co-creation framework cross-appropriates the DoSM for the purpose of design applications. Its utility is validated and valued through development within a dedicated discourse community, as recommended by Warfield's original (scientific domain) application. Further development through research into systems design co-creation will be necessary to yield a validated set of components to complete a working corpus. Based on the knowledge contributions of dialogic design science and the current research, we can propose a framework of components of principles and methods within the DoSM domains (Table 2).

Table 1 DoSM for co-creation in four contexts

	Lab	Studio	Arena	Agora
Co-creation structure	*Core co-creation*	*Team co-creation*	*Stakeholder co-creation*	*Value co-creation*
	Defining and creating methods, theorizing from arena practice	Process and workshop design, evaluation, method selection and stakeholder discovery	Facilitated events, stakeholder design engagements	Co-facilitated public engagement, focus on shared citizen issues in inquiry
Design function and process	*Proposition design*	*Concept design*	*Shared model design*	*Futures design*
	Proposing theory and method, models for applications, research	Designing session and workshop concepts, testing methods	Stakeholder creation, ownership of actions, decisions	Citizen co-creation of proposals for future policy, programmes, scenarios
Outcome	*Process innovation*	*Methods and prototypes*	*Models, decisions*	*Policies, public goods*
	Theory of use, novel methods, new practices	Studio products used in arena workshops	Stakeholders co-create working models for action and decision making	Citizens develop proposals for change and future public goods

Table 2 Framework of co-creation domain components

1. Foundation domain	
	Component 1: Axioms (seven dialogic design axioms)
	Component 2: Definitions
2. Theory domain	
	Component 3: Principles
	Component 4: Context theory
	Component 5: Ontological participation
	Component 6: Theory of action intervention
3. Methodology domain	
	Component 7: Roles and controls
	Component 8: Workshop process staging
	Component 9: Modes of inquiry
	Component 10: Modes of design
	Component 11: Modes of anticipation
	Component 12: Representation methods
4. Application domain	
	Component 13: Co-creation workshop: dialogic design co-laboratory (arena)
	Component 14: Stakeholder search conference (arena)
	Component 15: Civic inquiry (agora)
	Component 16: Observatorium (agora)

The co-creation framework proposal originates from the seven axioms instantiated in dialogic design science, which stand as first principles that might apply to all stakeholder co-creation, decision making, and public participation. A total of 16 components are proposed as options to develop as a framework for systemic design co-creation. These extend from the 16 components defined by the Christakis and Flanagan (2011) framework, and an attempt is made to maintain consistency with the original model. However, it may not be necessary to develop all components for a new framework; these are proposals being evaluated in different stages of development.

The proposed domain model serves as a synthesis of the study, incorporates the learning from the prior DoSM cycles performed for dialogic design, and presents a resolution to the drift of practices in design co-creation. These three trajectories of the study—theoretical, methodological, and praxis—might each afford an independent track of continued research and improvements to practice.

Foundation Domain

Foundation: Axioms

The seven definitional axioms[10] represent a foundation for a science of co-creation through collective cognition (dialogue). Axioms precede design principles for the development of engagement practices. The seven are codified as core functions in practices of collective cognition for collaborative action. They were proposed (and articulated by argumentation) as the minimal, meaningful, necessary functions for supporting rigorous dialogue for social systems design. Therefore, they can be expected to be equally meaningful to design co-creation for dialogic design processes. The seven axioms are summarized as follows, in their canonical numeration, agreed titles, brief definition, and the author whose work is attributed to the discrimination of the axiom:

1. *The Complexity Axiom*: Observational variety must be respected when engaging observers/stakeholders in dialogue, while making sure that their cognitive limitations are not violated in our effort to strive for comprehensiveness (John Warfield).
2. *The Engagement Axiom*: Designing complex social systems, such as for healthcare, education, cities, and communities, without the authentic engagement of the stakeholders is unethical and results in inferior plans that are not implementable (Hasan Özbekhan).
3. *The Investment Axiom*: Stakeholders engaged in designing their own social systems must make personal investments of trust, committed faith, or sincere hope, in order to be effective in discovering shared understanding and collaborative solutions (Tom Flanagan).
4. *The Logic Axiom*: Appreciation of distinctions and complementarities among inductive, abductive, deductive, and retroductive logics is essential for collective futures creation. Retroductive logic (referred to in design as backcasting) makes provision for leaps of imagination as part of value- and emotion-laden inquiries by a variety of stakeholders (Norma Romm and Maria Kakoulaki).
5. *The Epistemological Axiom*: A comprehensive human science should inquire about human life in its totality of thinking, wanting, telling, and feeling, as indigenous people and the ancient Athenians were capable of doing. It should not be dominated by the traditional Western epistemology that reduced science to only intellectual dimensions (LaDonna Harris and Reynaldo Trevino).
6. *The Boundary-Spanning Axiom*: A science of dialogue empowers stakeholders to act beyond imposed boundaries in designing social systems that enable people from all walks of life to bond across possible cultural, religious, racialized, and

[10] The seven definitional axioms of dialogic design science had evolved over a decade of practice and reflection and were instantiated as seven axioms in 2012 (with the addition of the final axiom 7). A tradition within the community of practice is to identify the original contributor of the proposal by name, without reference to a specific work but by affirmation.

disciplinary barriers and boundaries, as part of an enrichment of their repertoires for seeing, feeling, and acting (Ioanna Tsivacou and Norma Romm).

7. *The Reconciliation of Power Axiom*: Social systems design aims to reconcile individual and institutional power relations that are persistent and embedded in every group of stakeholders and their concerns, by honouring requisite variety of distinctions and perspectives as manifested in the Arena (Peter Jones).

Foundation: Definitions

Definitions are proposed as necessary for each stage of development, and for this article proposal, a small set of definitions are provided for the understanding of propositions. Definitions from the dialogic design science canon (where relevant) are selected for the developing framework.

- *Collaborative Foresight*—A model of Structured Dialogic Design oriented towards collaborative futures, where long-term systemic problems are engaged through strategic foresight by engaging multiple stakeholders in collaborative problem identification and strategic resolution.
- *Dialogue*—The engagement of observers/stakeholders in discovering meaning, understanding, wisdom, and actions by means of structured inquiry.
- *Interpretive Structural Modelling*—A matrix algebra method developed by John Warfield, based on the forced juxtaposition of statements to assess systemic relationships in terms of their directional influence. ISM is employed in defining the influence structure (systems of challenges and solutions) represented in an SDD influence map.
- *Leverage*—Solutions that convey a comparatively high degree of influence on other solutions and challenges. In SDD participants assess how collective progress on a deep challenge "leverages" progress on other challenges in a system.
- *Structured Dialogic Design* (SDD)—A registered service mark of the Institute for 21st Century Agoras for the multi-stakeholder dialogue engagement method for collaborative challenge resolution. SDD is an evolution of the practice of Interactive Management developed by John Warfield and Alexander Christakis and is mediated by one of several software systems, including the CogniSystem and logosofia.
- *Triggering Question*—A thoughtfully defined prompt that combines specific boundaries with strategic ambiguity. The focus of inquiry is developed over a period of consultation with sponsor team advisors and the stakeholder candidates for a dialogue. The triggering question evolves as the design team learns about participants' contexts through stakeholder discovery, and is typically presented in early stages to stakeholders, is evaluated through interviews and trials, and is presented as final in an Arena dialogue event. A triggering question frames the strategic intent of SDD and guides the generation of all challenge/solution group work. The common format for a triggering question is a simple question structure, naming the semantic form being elicited (challenge, solution) for a specific boundary in a specific timeframe:

Challenges: "What are the challenges we must face in addressing anticipated climate change impacts by 2025?"
Solutions: "What social and technological options are required to address this system of climate challenges by 2025?"

Theory Domain

Theory: Principles

What set or sets of theory-based design principles ought to be adopted for a systemic framework for social systems design? We can propose two sets of principles, which may be characterized as levels of design.

- Dialogic design science—Seven principles for guiding effective social system co-creation practices (e.g. collaborative efficacy)
- Systemic design—Ten principles for value discovery and systems design from systems and design theory (e.g. design viability)

Dialogic Design Principles

The original seven principles in the DoSM for dialogic design science are based on designing conversations for collective cognition and action based on derivatives of requisite variety. These seven requisites are documented in Christakis and Bausch (2006) and include the following (short labels with reference to author):

1. *Law of Requisite Variety* (Ross Ashby) is a central principle of dialogic design science and the foundation for the derived principles in the theory, based on Ashby's (1958) rule that variety in a system must be controlled or mediated by equal or greater variety in a control system.
2. *Requisite Parsimony* (G.A. Miller, 1956) is based on the limitation of short-term memory, the psychological principle of the attention to 7 +/− 2 chunks of information in a short-term presentation. Warfield proposed that when individuals are in problem-solving situations with other participants, short-term attention becomes limited to 3 +/− 0 units of information.
3. *Requisite Saliency* (Boulding, 1966) states that the relative saliency (distinctiveness) of observations can only be understood through comparisons within an organized set of observations.
4. *Requisite Meaning and Wisdom* states that meaning and wisdom are produced in a dialogue only when observers search for relationships of similarity, priority, and influence within a set of observations. This principle is attributed to C.S. Peirce's abductive logic (Frankfurt, 1958).

5. *Requisite Authenticity and Autonomy* in distinction-making demands that during the dialogue it is necessary to protect the autonomy and authenticity of each observer in drawing distinctions (authorship attributed to Tsivacou, 2005).
6. *Requisite Evolution of Observations* states that learning occurs in a dialogue as the observers search for influence relationships among members of a set of observations (authorship attributed to Kevin Dye, Christakis & Dye, 2008).
7. *Requisite Action* states that action plans to reform complex social systems designed without the authentic and true engagement of those whose futures will be influenced by the change are bound to fail (attributed to Laouris and originally suggested by Özbekhan, 1969).

The dialogic design principles satisfy the theoretical requirements for stakeholder co-creation, for designing and managing collective conversations for understanding complex shared problems and reaching consensus on action. The principles are developed from a pragmatist orientation, consistent with constructivist or critical realist epistemological perspectives. From a constructivist perspective, the principles afford voluntary participants the context for reaching collective awareness and a common mental model (known in SDD as a "consensual linguistic domain"). From a critical realist perspective, the principles enable organizers following these methods to reliably structure and facilitate co-creation workshops with high probabilities for successful outcomes.

Systemic Design Principles

To develop a working theory for systemic design, the author (Jones, 2014) formulated a series of ten principles that demonstrated the correspondence between systems and design theoretical principles for social system and sociotechnical design problems. Systemic design principles enable practitioners to develop systems design proposals and concepts supported by compatible systems science and design concepts. The prospects for value discovery (identifying high-potential situations for shared value in social systems) and design viability (continued value and duration) are amplified, employing the ten principles in design practices. The following brief descriptions describe the principles, which are fully detailed in the reference:

1. *Idealization* is the principle of identifying an ideal state or set of conditions that compels action towards a desirable outcome or signifies the value of a future system or practice.
2. *Appreciating Complexity* acknowledges the dynamic complexity of multi-causal wicked problems and the cognitive factors involved in understanding the relationships that indicate problem complexity.
3. *Purpose Finding* describes that purposes do not exist independently of observation in language, but can be determined by agreement and therefore designed or redesigned.
4. *Boundary Framing* is defined as the principle of determining the most effective fit between a concept and its target environment.

5. *Requisite Variety* in design proposes that, whether in a social system or information system, the functional complexity of a given design must be calibrated to and provide sufficient options for interacting with the known and potential factors of its target environment's complexity.
6. *Feedback Coordination* is a principle describing the function of identifying critical feedback relationships (first-*n* order) in social and technological systems, for coordinating the dynamic fit to environmental and contextual functions.
7. *System Ordering* defines the essential function of design as skilled activity, as all information, assets, organizations, and social systems are ordered in meaningful ways by human custodians. Designers define humanly useful structures that enable visibility and salience within complex situations.
8. *Generative Emergence* is a principle for selecting emergent manifestations for design signification. *Compositional* emergence manifests in design activity as an outcome of *ordering* or the construction of artificial micro-systems for adapting an artefact to environments. *Created* emergence manifests from *organizing* systems, which include physical connections, designed forms, organizing processes, and the synergies that emerge from among these functions.
9. *Continuous Adaptation* is the principle of maintaining a preferred system purpose and objectives (or desiderata) throughout the life cycle of adaptation, conformance to environmental demands, and related system changes.
10. *Self-organizing* in design enables actions that increase awareness, incentives, and social motivations to accelerate organizing behaviours.

Theory: Context Theory

The DoSM model supports the development of theory for interpreting and anticipating the function of principles. Theory articulates propositions (e.g. as a Lab function) that might inform and validate effective practices in the Arena and Agora. Component 4 proposes a theory of context for application of design principles, which in this case is a systems theory of the application of principles in design contexts.

Contexts can be defined in the case of systemic design as the containing boundaries for defined systems of interest. A defined boundary specifies the context for designing functions and artefacts that fit the environment within that boundary. Most systems theories offer a model of nested containing systems that might be adopted as context theories. Methodologically, Bertalanffy's general systems theory, Miller's living systems theory, Jantsch's evolutionary systems model, Luhmann's social systems theory, Bronfenbrenner's bio-socioecological model, and Wilber's integral theory would be viable candidates to adapt as context theories for aligning design aims to actions in an environment.

Two sets of principles apply to two boundary frames, which both operate within different contexts, (a) the context of conversation for collective action and (b) the context for system-level design. Both are theorized as necessary in support of requisite variety of (a) stakeholders to the problem context and (b) design options to the future environment of social/user participation. If we designate a third system boundary, temporality, we might introduce principles and theory for anticipatory design in future system contexts.

In the current prospectus, we reiterate the design domains (Fig. 1) as the context theory applicable to process, policy, service, and other systems design problems. The four design domains represent four levels of system, distinguished by inherent social complexity necessitated by the domains in which design decisions and transformations are proposed. Technical complexity (theoretically) can be bracketed or isolated by design for interfaces rather than assuming the designer must have technological mastery. The four levels reveal incommensurable complexity, in that complexity within a higher context (e.g. social or organizational) does not correspond to complexity in services or artefacts, and vice versa. If this is the case, expertise and methods from one level may have minimal transfer to the others. While it is possible for a skilled organization to maintain competencies in each domain, this remains atypical and (excepting a small number of major design firms) this attempt can diffuse the position and differentiation of a design practice.

The four domains entail design processes for the following:

- **D1.0**—*Artefacts*: Artefacts are objects and communications designed for bounded purposes or that support a product or service. Complexity is manageable by a small design team. Systemic design principles apply to the containing systems (contexts) for artefacts.
- **D2.0**—*Products and Services*: Context of value co-creation with users (including service design, product innovation, multichannel, and user experience), design as defining and integrating user functions into larger systems and platforms. Complexity as *complicatedness*, manageable by full-service design team with client organization. Systemic design principles apply to designing service systems and interactive interfaces.
- **D3.0**—*Organizational Transformation*: Organizational process change for operationally closed social systems, design of work practices, strategies, and organizational structures. Dynamic complexity requires a specialized design team and full client organization participation. Systemic design and dialogic design principles apply to process design and decision making.
- **D4.0**—*Social Transformation*: Complex, multi-stakeholder, open social systems: design for complex societal situations, social systems, policy making, and community design. Social complexity requires specialized design and system facilitators, with requisite variety of core team for stakeholder participation management. Systemic design and dialogic design principles apply to process design and decision making.

Other publications have discussed the design domains (Jones, 2014) in more detail, and these references will serve as additional information.

Theory: Ontological Variety in Participation

Theoretical support of a domain of design model (DoDM) must account for stakeholder and participant variety in co-creation, including sampling, selection, and anticipated system participation. A general theory of participation across dialogic and systems design would entail ontological variety or a model of committed stakeholders that corresponds to the multiple social systems to which they belong.

A theory of requisite stakeholder variety has been developed for anticipatory studies (Jones, 2017) as a model for participant selection in foresight strategy. In this model, two supporting theories include the cybernetics principles of requisite variety (Ashby, 1958) and second-order control (von Foerster, 2003). These inform a theory of stakeholder discovery that balances selection and variety of disciplines, perspectives, authority, diversity, and stake-ness among participants.

Undersampling stakeholders with investment in the "real" or external system environment leads to insufficient knowledge contribution and commitment to future outcomes. In this approach, multiple worldview perspectives and temporal preference were integrated with a reference stakeholder selection model (the "5 I's" from Christakis & Bausch, 2006).

Latour's (2013) modes of existence worldview typology is further integrated as a social theory of requisite perspectives relevant to complex social concerns, where many legitimate viewpoints and future stakes might be identified in stakeholder sampling. The 15 "modes" represent articulated, orthogonal, yet overlapping positions that define ontological perspectives from recognized institutions in modernist societies, such as law, science, fiction, technology, religion, and so on. These are rendered as institutional beliefs or alliances that would signal and construct a stakeholder's perspective as representative for that institution's commitments and normative relations. Latour's model prescribes a process of "crossings" or value tensions identified in the relations between ontological modes, such as a crossing of reference (scientific worldview) and fiction (essentially, imaginative arts); this might not only entail scientific imaginaries but the adaptation of arts within scientific knowledge translation or the shift in scientific values to include radically subjective meanings. Stakeholders can thusly be identified within modes and crossings that enrich and "requite" the necessary complexity within a problematic system inquiry. The function of crossings between modes is essentially the model used in stakeholder discovery to represent (and to reduce or absorb) variety across dimensions in order to reach a larger proportion of desired stakeholder identifications associated with the problem for which requisite variety is sought.

Requisite stakeholder variety provides a reference model that classifies three modes of stakeholder identification: social diversity, design problem categories, and worldview (ontological preference). At minimum the stakeholder sampling model provides a checklist that exposes possible risks and blind spots in the available composition of stakeholders or experts. The model further provides a schema for identifying value conflicts between worldviews and other attributes associated with known stakeholder interests. The requisite stakeholder variety model for stakeholder discovery was designed to address the necessary variety in systemic design, particularly for strategic foresight in social transformation projects. It has been further developed in foresight workshops and as a reference model for anticipatory policy research.

We can propose that careful incorporation of the modes of existence to the stakeholder model will make a significant difference in selecting participants with sufficient variety to represent the broadest ranges of design options and commitments to social action. The canonical analysis model for stakeholder variety had previously addressed variety with two axes, of stakeholder "relations to the problem" and "social diversity values" such as education, age, gender, and culture. We add the third dimension of ontological commitment (mode) and allow for crossings of three dimensions to produce a reference for managing high-complexity sampling across perspectives and knowledge domains.

Theory: Theory of Action Intervention

Dialogic design and systemic design entail a wide range of approaches to activating change in social systems. Theories of change are working hypotheses and observations that explain the transition from a current state to a desired outcome for transformative change in organizations or systems. Theories of change are references to models of practice, not predictive theories supported by social science. They have been evolved from a concept within organizational development practices to more well-defined social change methodologies such as developmental evaluation (Patton, 2010) and transition design (Irwin, 2015). While these methodologies can be employed within specific programmes, a general "theory of change" applicable to system change would be misleading. The distinction of "theory" in change refers to the shared mental model of change outcomes expected from actions and choices in a planning context, the "shared idea" among participants about the occurrences leading to change.

Theories of change are necessary tools for action planning for social system change and are meant to be examined and adapted for particular programmes. While the methodologies of Patton, Irwin, and Westley (Westley, Zimmerman & Patton, 2009) provide methods and models, successful case studies, and adaptations, they are not directly appropriated within change projects or action planning.

The Patton and Irwin models correspond to systems methods (with respect to boundary critique, critical system analysis, and social complexity). These are system-level frameworks that developed explicit theories of change and methods for engagement and fieldwork analysis. And as most systems methods, they lack an explicit methodology for stakeholder engagement.

Stakeholder theory appears to be underdeveloped within system change methodology, as there is little development to inform the practices and forms of action expected of stakeholders in change planning. Dialogic design has evolved a practice-based stakeholder methodology from the original theory of Hasan Özbekhan (1969), who had first articulated the ethical necessity of involving "the users" of system change, the stakeholders within the social system. The direct entailment of stakeholders in social systems design and change through committed action planning was developed in Warfield's Interactive Management methodology.

There are two definitive modes of intervention for action in the frameworks. For Structured Dialogic Design, the engagement method goes far beyond co-creation as participation into the formulation of a consensual linguistic model constructed in dialogue participation. The ISM algorithm is used to structure super-majority votes on relationships of problems and actions to each other, creating a high-consensus influence map. An influence map (in SDD presented as a directed acyclic graph of influences) describes the network of leverage from deeply influential solutions or actions on the outcomes of interest. Similar in respect to outcome mapping, the ISM influence map has a much higher degree of commitment across highly mixed groups of stakeholders with respect to worldviews and power.

Systemic design is inherently situated to design and plan interventions that shift systems and practices to the future outcomes preferred by stakeholders. Therefore, the stakeholder variety theory is essential to any change model adopted in the framework.

Methodology Domain

The Methodology domain of the DoSM model represents a series of practice models developed from reflective analysis of requirements in the Arena. From direct experience with systemic design engagements in practice, the six methodological inquiries offer opportunities for deeper development of evolving methods and to assess their relationship to the theory base.

The following six methodology components are proposals for further practice research within the framework.

Methodology: Roles and Controls

Each stage in the systemic design domain model may require different roles and process controls for managing process, engagements, and design outcomes. Dialogic design identified a Dialogue Management Team consisting of five core team roles. Depending on methodology and the process for control, we propose the following:

- *Lab and Studio*
  - Principal designer
  - System researcher/analyst
  - Design/researcher
- *Arena and Agora*
  - Engagement manager
  - Dialogue facilitator
  - Visual recorder/designer
  - Co-facilitator/coordinator

- *External roles*: Three roles developed in SDD practice might be used in systemic design:
  - Project sponsor—Sponsor organization lead with a commitment to stakeholders and outcomes
  - Organizational broker—Direct project support within the organization to manage the design process, relationships between the design team and organization, and inquiries
  - Logistics coordinator—A coordinator within the organization for process and logistics

Methodology: Workshop Process Staging

The practice models of dialogic design strongly promote the staging of workshop (co-laboratory) engagements in the Arena and Agora. Stages follow an ordering based on the necessity for progressive evolution of learning and design decision making and the process of moving from problematiques to resolutique (solutions) and action. The following stages are typical, though not "canonical" in dialogic design and systemic design:

- *Lab and Studio*
  1. Discovery (theory framing)
  2. Learning
  3. Exploration
  4. Design inquiry
  5. Evaluation
- *Arena*
  1. Discovery (problem framing and stakeholder finding)
  2. Definition (problem structuring)
  3. Design (scenario)
  4. Action planning (strategy making)
- *Agora*
  1. Discovery (problem framing and finding publics)
  2. Problem inquiry
  3. Future co-creation
  4. Movement building

The identification and labelling of design process stages is a process that creates a consensus mental model for constructing the anticipation of engagement activities. Many different lexical labels could refer to essentially the same set of activities, between design process models. The labelled design process stages here signify both well-established references in the literature (discovery, definition, design) and several novel propositions for the Agora context, to propose a futures-inquiry process for publics, which may have undefined or undeclared agendas.

Methodology: Modes of Inquiry

Churchman's (1971) inquiring systems provide a general basis for the modes of inquiry across all contexts, as follows:

- Inductive
- Hypothetico-deductive
- Dialectic
- Critical, multi-perspectival
- Pragmatic, synthetic, holistic

Methodologically we might clarify and add:

- Peircean, abductive (formal abduction)
- Retroductive[11] (retrospective chaining from future state)
- Normative (value-driven)

Churchman's systems for inquiry remain the foundation model for identifying logical modes for problem investigation. The systems perspective of Churchman's model can be extended with formal abduction and retroduction, and normative evaluation as inquiry.

Methodology: Modes of Design

Systemic design is an integration of design methods with systems theory and approaches (Jones, 2017).

Considering the design domains construct of Design 1.0–4.0, we might explicitly distinguish the relevant modes of design inquiry and processes considered relevant in these domains.

1. Communications design
2. Product and service systems design
3. Organizational and social purpose design
4. Complex social systems design

Of course, it would be possible to introduce a dozen or more emerging and specialized design approaches that are constantly in formation across similar contexts.

[11] Retroductive inquiry has been known for some time as backcasting and has been used recently in social science work in the dialogic design practice, e.g. Romm, N.R. (2013). Revisiting social dominance theory: Invoking a more retroductively-oriented approach to systemic theorizing. *Systemic Practice and Action Research, 26*(2), 111–129.

While other models of design for complex sociotechnical and social systems are proposed in literatures and practice (e.g. translation design, transition design, regenerative design, design futures), these are also types of approaches that fulfil purposes of the four design domains. The four design domains afford a theoretical contribution of isomorphic types with differentiated purposes and objects of design specific to the mode, and with graduated complexity at each level. The emerging purposeful design modes support methodologies that accomplish the aims of (primarily) one of these domains.

Methodology: Modes of Anticipation

Modes of anticipation account for the methods employed in individual and collective reasoning about future change and system evolution, as follows:

- Historical cycles/wave theory
- Normative planning
- Scenario design (narrative patterning)
- Envisioning (group prospection)
- Backcasting (retroduction)
- Influence structuring
- Optionality analysis
- Emerging perspectives

Methodology: Representation Methods

There might conceivably be dozens of representations in systemic design, from formulation of early-stage constructs to visualizing large-scale social systems. Representations are nominal rather than categorical—they cannot be reduced to a baseline set of primitive types, and they can be adapted and combined in unexpected ways. The following list might be considered only a partial inventory of common representations by type employed in systems design studio and arena practices:

- Systems formalisms
- Systems analysis and design methods
- Tables and structured text
- Matrices
- Slope and curve plots
- Statistical summary diagrams
- Rich picture and notional system diagrams
- Concept maps
- System models
- Outcome maps
- Synthesis maps and Gigamaps
- Hierarchies and tree structures

- Process models and flowcharts
- Organizational and stakeholder diagrams
- Network diagrams
- Function hierarchies and decomposition models
- Activity system models
- Cyclic and wave models

Application Domain

The Application components identify four contexts for co-creation in the Arena and Agora. Two Arena contexts (sponsored, stakeholder-driven) include the co-laboratory and strategic dialogue. Two Agora contexts include an open civic inquiry and the (sponsored) observatorium. Note that these application contexts are co-creation practices in systemic design, methodologically informed by dialogic design. They are applications developed in the DoSM (Lab and Studio) for hybrid models of engagement, informed by methodology and practice from SDD engagement.

Application: Co-creation Workshop—Dialogic Design Co-laboratory (Arena)

The foundation model, from which the other workshops are derived, is the dialogic design co-laboratory, based on Structured Dialogic Design (SDD). The canonical method is described in Christakis and Bausch (2006), with the only major changes to the process being the evolution of software for co-lab management and influence structuring (*Cogniscope 3* and *logosofia*).

Application: Co-creation Conference—Strategic Dialogue (Arena)

Strategic dialogue is a general framework for stakeholder decision making in which selected methods from dialogic design are employed, following the principles, to accomplish other strategic goals that might not be enabled with a canonical SDD co-laboratory.

Application: Civic Inquiry (Agora)

The Agora contexts are open public dialogues held as inquiries for critical issues of interest to communities and publics. The "civic inquiry" is an open-ended application that can be adapted to principles and methods of dialogic design to promote co-creation approaches within a dialogue setting.

Application: Observatorium (Agora)

The observatorium, based on Harold Lasswell's social planetarium (Lasswell, 1959), is a means for collective envisioning of alternative future proposals, engaging citizens in rational discourses to arrive at possible scenarios and options. This methodology is being employed in Greece with the Demoscopio programme (Kakoulaki & Christakis, 2018), which involves a series of installations and engagements with towns and their citizens. Toronto's *Design with Dialogue*[12] programme has evolved over this period as a social observatory and open civic engagement process. These two, and other projects like them, provide guidance for organizers of public democratic contexts for civic policy co-creation. In some cases, civic co-creation provides a basis for convening the intellectual capital and early participants for social movements.

Summary

This domain model represents a framework proposal for further application and inquiry. We might expect to evaluate at least a complete cycle of new documented practices across an entire large case to produce a significant research account. To articulate a full framework, we would assess the full set of components across Theory, Methodology, and Applications, their support (or exceptions) for relevant cases, and their rationale for selection. Their development would also require, by necessity of requisite variety, co-creation by practising members of the discourse community.

Discussion and Recommendations

Following a study from practice-based design research, a model and proposal are advanced to resolve well-known concerns in co-creation and social design practices. The primary social purpose of the study is to support a theory of efficacy for multi-stakeholder collaboration for complex design problems, from the early-stage ideation to team and stakeholder decisions and social change outcomes. Building on the reference model of Warfield's Domain of Science Model, a process model for systemic design theory and practice is defined that should produce significant collective stakeholder efficacy within a stage of design or action.

The major practice issue addressed is that of anticipating and advising effective collective decision practices for projects with stakeholders of mixed power and

[12] *Design with Dialogue* is a monthly open dialogue series at OCAD University in Toronto, which holds a continuous learning community for organizational and social transformation through design facilitation of dialogic practices. Hosted as a public agora since 2008, the online site is found at http://designwithdialogue.com.

culture. Our societies continually demonstrate the inability to gain agreement for policy and planning guidance for complex societal problems. The dialogic design practice was developed for dialogic methodologies to enable mixed stakeholders to observe a rigorous design-decision process. *Design* is identified here as an integrated activity of the dialogic process, with the co-design of future options and action scenarios. Systemic design is a *design*-led practice that integrates dialogue in co-creation for sensemaking and decision making, as necessary for understanding system perspectives across stakeholder worldviews, and argue design solutions and propose joint actions. They are highly complementary, with nearly identical values and principles in most cases, but with very different practices, methods, and genres of *design*.

Another major issue addressed by the framework study is its ability to confront the continuing inability in modern society to organize and produce democratic, citizen-informed change in critical complex problems. We live in a time of an oppressive, socialized incapacity of institutional cultures to motivate action beyond extrapolations of false progress. Whether dealing with urbanization, surveillance and security systems, climate and environmental change, corporate economic hegemony, or unresponsive political systems, the embedded bureaucracies of corporate and government power have been sustained by decades of dysfunctional decision practices. Design thinking and conventional genres of design (e.g. communications and service design) have demonstrated no theory of change to democratic power or shared decision making and, in fact, have often been appropriated and directed by the benign fronts of invested power.

Dialogic and systemic design practices are not merely problem-solving processes employed for complex design problems within organizations sharing common purposes. Systemic design is uniquely efficacious in addressing root causes in complex problem systems and in reaching consensus on high-leverage design options and change scenarios. Further beneficial outcomes will result when using the framework as guidance to employ co-creation methods in various contexts with more practitioners.

Co-creation and creative engagement methods have proliferated in recent years, following an increasing demand for design co-creation and co-design in corporate and public sectors. A wide variety of design-trained practitioners (industrial, user experience, strategic, service, and various interdisciplinary designers) and organizations trained in design thinking have socialized creative approaches to group work and problem resolution. However, the major design disciplines have not taken the intellectual lead to study their preferred approaches to co-creation or creative stakeholder engagement—nearly all work found in the grey literature and online shows up as practice methods from design firms or proprietary design firm "methodologies." Many practices employ a false-canonical approach to co-creation, by publishing or prompting bespoke process models or as bodies of local knowledge available to certified practitioners.

Among even advanced practitioners, the prevalent modes of co-creation commonly mix a design thinking methodology with granular creative methods, such as the techniques in IDEO's human-centred design, large group interventions such as

Open Space, and the ubiquitous brainstorming with sticky notes. Research-supported co-creation methods such as Structured Dialogic Design, Team Syntegrity, and Simplexity (Basadur, Basadur, & Licina, 2013) are rigorous, require training to facilitate well, and are (therefore) fairly uncommon in design practice. While certainly not harmful, the creative deployment of such modes of co-creation amounts to craft practice, often wholly dependent on facilitation skill.

A recent development in the systemic design literature is found with the HEC model of design facilitation (Aguirre, Agudelo, & Romm, 2017), developed from observations in the arena of practice. Their methodology proposes a core model for formation of multi-stakeholder design engagements, focusing on facilitation practices and the structuring of co-creation activities. Three process dimensions of co-creation are defined for designing events for participation (genre and method), intention (purpose and outcome design), and function (structures for usability and feasibility across process goals). Three modes of event participation are proposed to calibrate the workshop genre and experience for particular participants: human-centred perspective, experiential, and creative modes. These can be tuned to contribute more or less of each, to customize a type of co-creation event with relatively high, medium, or lower contributions of each mode. This model could also be used to measure differences between other cases for assessment of collaborative efficacy, with relatively more or less creativity, participation, or experience. Facilitation models and genres of co-creation (styles associated with cultural expectations) offer a fruitful area for future development. Such a facilitation methodology might be compatible with the contexts of a co-creation framework, suggesting event-level design facilitation techniques consistent with any engagement adopting principles and methods in the framework.

Evaluating Process Models

There are few standard or well-documented practices supported by research evidence that can validate comparative efficacy among co-creation modalities. In the absence of consensus or standards, we can move ahead with our craft practices shaped by our training and experience with clients, or we can develop guidelines from studying methodology and observing years of successful practices. In this (latter) case, we have further developed sets of principles that other practitioners might employ for their methods and participatory co-creation practices.

If there are no grounds for comparative selection for given types of problems or stakeholders, we cannot determine whether another method would have been superior to a selected method (after having implemented a given practice). We cannot determine in advance the collaborative efficacy of a given method with a particular group of stakeholder participants. We would only have practitioner experience to determine whether the choice of, for example, a structured Team Syntegrity (Leonard, 1996) would produce superior intermediate outcomes and ultimate change compared to the unstructured Open Space (Owen, 1987) for a given context.

In fact, this is also the case with design methodologies (even if not so for research methods, which can be forecasted to have better or worse fit or contribution in types of projects). There is no perfect design process. When we choose a suite of methods and techniques for design process, we employ heuristics from experience, as well as the techniques perfected by the design team and the expectations of a client or sponsor for certain outcomes.

In contexts for co-creation we must address a complex mix of design and method selection factors, based on rationale and conditions that we have only touched upon in this framework study. Even so, the selection of co-creation method often remains entirely a matter decided by sponsors and a design team and their advisors. Typically an expert facilitator on the team will recommend the method for which they are known as expert. We find only a small number of other frameworks or "meta-methodologies" defined for purposes similar to contexts of co-creation. Design toolkits are typically practitioner guidelines, such as the IDEO Design Kit[13], which are methods and consensus practices associated with general design thinking approaches. Among change practices, Liberating Structures[14] is a collection of prior, well-established methods for facilitation purposes loosely organized in a practitioner framework. Practitioner frameworks rarely support the method choices or patterns with research guidance or references. In practice, most practitioners demonstrate clear preferences and strengths in certain methodologies and styles of practice. Experience with methods may be more of a determining factor in their choice than abstract selection rules.

In systems practices we find a tradition of analytical frameworks for integrating and selecting methods for appropriate problem types. In systemic research for social systems, Midgley et al. (2013) proposed a framework for evaluating efficacy of problem structuring methods used in systems studies and outcomes. The framework distinguishes evaluation constructs for context, purpose, methods, and outcomes, which could be a compatible set of evaluative categories for the DoSM. Mingers and Rosenhead (2004) evaluated a wide range of multimethodology studies to propose a framework for selection and integration of multiple problem structuring methods for a context. Midgley et al. (2013) developed an evaluation model compatible with Mingers, with criteria for assessing the contribution of problem structuring methods to complex problem contexts. These are beneficial contributions to methods, evaluation, and theory from classical systems methods, problem structuring studies, soft systems, and operational research. These approaches seem entirely applicable to the Design 3.0 and 4.0 domains as complex multi-stakeholder design contexts. Users of this framework might draw directly on these foundations in the systems disciplines for guidance in multimethodology, problematizing, and selecting and assessing rigorous group methods.

[13] Design Kit from IDEO.org http://www.designkit.org provides a set of handbooks, a website, and resources for learning basic designing practices for human-centred design.

[14] See Liberating Structures: Lipmanowicz, H., & McCandless, K. (2014). *The surprising power of liberating structures: Simple rules to unleash a culture of innovation.* Seattle, WA: Liberating Structures Press.

Conclusion

The chapter presents the findings from an extended period of observations and action research practices that inform a new framework for co-creation practices in systemic design, based on established work in the systems sciences. The framework provides a means of integrating and bridging systems theory-based principles, structured dialogue and group dynamics, and design methodology. This aims to provide a sufficient (requisite) methodology for stakeholder design for social complexity, enabling its users to define interventions and options for social design problem resolution.

The central purpose of the study is to introduce processes known to improve collaborative efficacy for design and decision making in multi-stakeholder co-creation. The framework will fail to accomplish these aims if not adopted in whole or part as a reference model or guideline for design practice. Another aim of the study is to propose and continue the development of a practice theory for systemic design, which might be adopted for convening practices and the management of large systems change programmes involving multiple venues and communities of participants.

Co-creation as a participatory group process has been developed effectively to date as a proprietary and craft practice within communities of practice. When we take this position, supported by the literature and field observations, the evolution of co-creation appears similar to other practice-led design methodologies in wide use, but unreported in scholarly studies. This publication aims to redress that gap in the progression of social science for complex design.

Design studies are not typically investigated as social science research, except for organizational studies of corporate design practices, creative teamwork, and similar boundary practices. However, design co-creation has grown to become a practice norm in many organizational settings and carries embedded values and social interactions that are accepted as productive or effective to design outcomes. We actually know very little about the social effects and influences of design values in co-creation, as researchers have a quite limited ability to instrument and observe changes in social practices resulting from design practice. Co-creation ought to be studied as a sociotechnical intervention, as a social technology with informal and canonical forms, explicit and tacit normative values, and communities of practice. Compared to previous social studies of enabling technologies, such as computer-supported cooperative work (CSCW) and learning (CSCL), we have not assessed the social functions of co-creation as a sociotechnical system of planning, decision making, and design. The current work is a proposal to formulate better models and categories for observation of meaningful operations across the many forms of collaborative design practice.

Finally, the concept of collaborative efficacy in multi-stakeholder participation is a central idea that might be observed and measured through criteria such as those developed in the framework proposition. For co-creation to be determined as "systemic" however, some manner of criteria and evaluations might be considered that could demonstrate how intended system-level outcomes can be achieved productively. A systemic design methodology ought to also foresee and resolve problematic organizational, social, and psychological constants affecting group sensemaking. Improving collaborative efficacy might serve as a motivating purpose for further social research into the activities and functions of co-creation in organizational and design contexts.

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A Framework for Complex Design: Lessons from Synthetic Biology

Chih-Chun Chen and Nathan Crilly

Abstract This chapter reports on the development of a general framework for describing complex design which can be applied in different design contexts to identify commonalities and discrepancies in the perspectives that people adopt. The framework was built from interviews with practitioners from the complex design field of Synthetic Biology. However, we demonstrate its broad relevance by applying it to describe the sociotechnical example of "designing out crime." The framework consists of three dimensions, each reflecting a different aspect of complex design, as described by the study's participants. The first of these dimensions is the characterization of system complexity, the second is the design objective identified with respect to this complexity, and the third is the design approach applied to realize this objective. Because of its domain-neutrality, the framework could assist designers working in different complex design contexts (e.g. swarm robotics, policy formation, and healthcare), to identify when they are addressing design problems that share fundamental similarities. The framework could also assist different designers working on the same complex design challenge to identify discrepancies in their complex design practices or problem framings. In the same way that complex design challenges are never truly "solved," the framework is not presented here as "finished," but as an empirically grounded work-in-progress. Studies of other complex design fields would further develop the framework, better supporting cross-domain knowledge-sharing in complex design activities.

Introduction

Many of today's design challenges[1] can be described as "complex" (or "wicked" or "systemic"). These challenges often relate to sociotechnical systems that behave in unpredictable ways and which have multiple stakeholders from different domains

[1] We use the terms "complex design challenge" and "complex design problem" interchangeably but tend to use "complex design problem" when referring to the problem itself (e.g. reducing crime in

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and with differing objectives. Complex design challenges demand design practices beyond those of traditional problem-solving, since tackling them requires multiple problem framings and perspectives. The fact that multiple domains are involved poses a significant challenge, since these different domains can have very different design practices and very different ways of "framing" or characterizing the challenge. At the same time, practitioners working in different design contexts may in fact share similar problem framings and practices, but these similarities are overlooked because each design problem is described in domain-specific terms. In order for practitioners and stakeholders of complex design challenges to effectively engage with each other, these similarities and differences need to be made explicit.

To provide a basis for sharing and comparing complex design practices across domains, we present a framework that represents the different aspects of complex design practice. This framework is based on an interview study with practitioners from the complex field of Synthetic Biology. Synthetic Biology is a field that designs and constructs new biological parts, "devices" (functionally significant sub-assemblies), and systems, or that redesigns existing natural biological systems for useful purposes (Benner & Sismour, 2005). However, in Synthetic Biology, the design practices adopted need to go beyond traditional "rational" approaches, which require a good understanding of how the system works. This is due to the non-straightforward relationship between the biological entities being engineered and the systemic behaviours those entities are designed to exhibit (e.g. producing certain quantities of a particular chemical product). Furthermore, Synthetic Biology encompasses several disciplines, spanning chemistry, computer science, molecular biology, engineering, and physics, and requires skills and knowledge from different domains. Capturing practitioners' descriptions of complex design in Synthetic Biology provides the opportunity to learn from experts who specialize in addressing complex design problems and who have developed practices to assist with this. By developing a framework to represent the variety of perspectives that those experts shared with us, we hope to assist people in other complex design fields reflect upon and communicate their own problems and practices. To illustrate this, we apply the framework to describe an example of a sociotechnical design context: "designing out crime."

Complex Design Problems and Practices

In recent years, engineering design principles have started to be applied in domains outside of those traditionally associated with engineering, many of them also involving systems that are difficult to understand, predict, or control or are otherwise labelled as "complex." For example, design principles are used by people working in domains as diverse as business strategy (Vinnakota & Narayana, 2014), policy formulation (Bobrow, 2006), crime prevention (e.g. Duarte, Lulham, &

a region of the city) and "challenge" when referring to the problem as something that needs to be addressed for a broader set of objectives (e.g. reducing crime for social improvement).

Kaldor, 2011), defence strategy (e.g. Tolk, 2012), healthcare systems (Clarkson et al., 2004), and biology (e.g. Fu, 2006). Furthermore, emerging and converging technologies have increasingly blurred the boundaries between the principles and practices that apply to designed artefacts and those that apply to naturally occurring systems (Chen & Crilly, 2014a, 2014b). For example, distributed computer systems and the Internet have been studied as natural ecologies (Forrest, Balthrop, Glickman, & Ackley, 2005; Gao, 2000), and complex sociotechnical systems are characterized as partially designed and partially evolved (de Weck, Roos, & Magee, 2011). As such, design principles are being used to understand and modify a great variety of systems that have very different kinds of elements (e.g. physical, chemical, biological, mental, social, logical), systems that have traditionally been the preserve of different disciplines (e.g. physics, chemistry, biology, psychology, sociology, computer science).

Complex design problems are problems where the success of the design is entangled with the characterization of the design problem itself. This might be because the requirements are highly sensitive to unpredictable contextual factors (e.g. designing built environments for crime prevention), or it might be because the relationship between the designed elements and the system properties is not well-characterized (e.g. genetically engineering cells to produce some chemical product). In both cases, there is an indirect relationship between the design of the system's elements (or the system's subsystems) and what the designer intends to deliver to the users or stakeholders at the system level. This can either be considered as a challenge or an opportunity: a challenge by those who invoke concepts of "wicked" (Rittel & Webber, 1973) or "ill-defined" (Visser, 2004) problems or an opportunity by those who aim for "complexity engineering" (Buchli & Santini, 2005; Abbott, 2006; Frei & Serugendo, 2011a, 2011b). Either way, the practices and principles used to tackle such design problems may diverge from those used to address the simpler design problems associated with traditional design practices (Chen & Crilly, 2016b).

For those adopting a "wicked problems" perspective, complexity lies both in defining the problem itself (framing) and striving for a solution. The majority of such problems involve a social system (or several interacting social systems), and often these social systems themselves constitute the stakeholders and designers. Here, there is a recognized need for making more fundamental changes to design practice so that systems thinking becomes integral to design activities. In systemic design (Jones, 2014; Sevaldson, 2011), the design problem and the design practices related to it together constitute a complex system having multiple stakeholders and interacting, coupled subsystems. Similarly, there is now a greater appreciation for the co-evolutionary nature of problems and solutions (Maher & Poon, 1994). No longer is the "solution" a static state to be attained; instead, design is characterized as a process of problem-solution co-evolution with a desirable trajectory (Wiltschnig, Christensen, & Ball, 2013).

Given the different efforts that have already been made to provide general principles, guidance, and methods for complex design, it is important that different design domains and the designers working in them are able to share knowledge and collectively harness insights; failure to identify such common ground leads to duplicated efforts and missed opportunities for building upon established bodies of knowledge in different domains. For example, the designer working out how to manipulate street lighting to try to reduce crime (Duarte et al., 2011) may benefit from the systematic experimental procedure of the Synthetic Biologist attempting to optimize the level of production of a particular chemical product in a biological system. However, only by describing complex design activities in domain-neutral terms can such potential commonalities be identified. Equally important is the ability to identify disparities in design practice or problem framing by those working on a common complex design problem; failure to identify such disparities is likely to result in misplaced efforts and poor outcomes due to incoherent solution strategies.

To provide a basis for sharing and comparing complex design practices across domains, we conducted qualitative interview studies in the complex design field of Synthetic Biology, inductively building a framework that represents different aspects of complex design practice. To clarify the different components of the framework and to demonstrate its cross-domain applicability, we also provide a short illustrated example of its application to the design of a built environment, specifically street lighting, to prevent crimes (for more details of research relating to this, see Jeffrey, 1977; Nair, Ditton, & Phillips, 1993; Crowe, 2000). However, we begin with providing a background to Synthetic Biology so that the context of the study can be understood.

Background to Synthetic Biology

Synthetic Biology is a field that explicitly frames itself as a design practice and employs many engineers to fulfil its ambitions. For example, the literature on Synthetic Biology clearly points to the central roles played by design principles such as compositional hierarchy, standardization, and modularity (Endy, 2005; Knight, 2005). The application of these principles is claimed to allow biological systems to be designed and constructed systematically, thus recognizing the significant contribution of conventional rational design approaches. However, the limitations of compositional hierarchy with respect to biological complexity have been acknowledged (e.g. Agapakis, 2014; Andrianantoandro, Basu, Karig, & Weiss, 2006; Kwok, 2010), challenging some of Synthetic Biology's fundamental assumptions. As such, Synthetic Biology is positioned as a field with engineering origins, motivations, and methods, but also as a field that is tackling complex design problems that are not entirely reducible to a traditional engineering approach.

In addition to the biological complexity of its entities, Synthetic Biology also faces challenges with respect to the social and ethical implications of the devices and systems being engineered (Anderson et al., 2012). For example, a system might be engineered to produce outputs that serve as food, fuel, perfume, or disease treatment; each of these may have implications for the human system of which they are a part. In comparison to other fields of complex design, Synthetic Biology has the advantage of receiving prompt and definite feedback on the success or otherwise of the design approaches that it has adopted. As such, Synthetic Biology is a valuable field to study when seeking to gain an understanding of the opportunities for applying design principles to complex design problems and the limitations of doing so. Those wishing to learn more about the field and its recent developments should refer to introductory reviews (Andrianantoandro et al., 2006; Purncik & Weiss, 2009) and the recent *Nature* (2014) issue focusing on the field.

Method and Participants

Between November 2014 and March 2015, ten expert participants were recruited into the study from institutions in Europe and the USA. Participants were selected for their background so that they collectively represented the interdisciplinary nature of Synthetic Biology design contexts. During recruitment, participants were given a brief account of the purpose of the study and participated on that basis.

Procedure

The interviews were conducted using a semi-structured protocol (Breakwell, 2006), with each interview lasting between 30 and 40 min. Remote video or voice calls were used when site visits were not possible. The interviews focused on both the design problems that the participants encountered in their own professional work and the design problems associated with the field of Synthetic Biology more generally (often, these overlapped). The interviews took a conversational form so as to accommodate and profit from the different perspectives taken by participants and to permit flexible exploration of the topics that were deemed to be important by each of them. However, to ensure that the discussion still centred on design complexity in Synthetic Biology, these conversations were also guided by a common script, addressing four main themes:

- How the participants' work fits into the field of Synthetic Biology as a whole (this was to put the participants' other responses in context and understand the nature of the specific problems they were addressing).
- The challenges faced by the participants in their work (this was to capture their characterization of the design problem(s) they were facing).
- The application of engineering and design principles in Synthetic Biology (this was to determine the perceived contribution that design had made to Synthetic Biology).
- The extent to which Synthetic Biology might be able to contribute back to the engineering disciplines from which it was first inspired (this was to identify any principles, methods, or techniques used in Synthetic Biology that could be generalized to address complex design problems in other domains).

With the participants' consent, interviews were captured using a digital audio-recording device. All recordings were then transcribed verbatim (totalling approximately 29,000 words) and augmented with descriptions of any visual materials presented during the interviews (e.g. pictures, books, objects). Transcripts were imported into qualitative data analysis software (ATLAS.ti) to permit the iterative coding process associated with a general inductive approach (see Braun & Clarke, 2006; Thomas, 2006). They were then coded by two researchers, one of whom was not directly involved in the interviewing process.[2] Both coders used the same iterative coding process to arrive at their own set of themes; examining the differences between the researchers' coded transcripts permitted the identification of additional themes and alternative interpretations of the data. After several coding cycles, the analysis had stabilized on the main themes and sub-themes that are presented in this paper. Although the analysis was conducted on full verbatim transcripts that reflected pauses, broken sentences, and repetitions, the quotations provided here have been edited for clarity, removing repetitions, pauses, and false starts.

Participants

In our sampling of participants, we covered the different "input domains" identified through reviewing the literature, namely, chemistry, computer science, molecular biology, engineering, and physics. All of our participants held doctoral-level research degrees (e.g. PhD), with 4 or more years' experience in the field. The majority of participants worked in research organizations, but two worked in commercial organizations (see Table 1).

Table 1 Summary of participants' backgrounds and experiences in Synthetic Biology

	Subject of highest qualification	# of years in Synthetic Biology	Organization type
SB1	Nonlinear dynamical systems and control	5.5	Research
SB2	Synthetic biology	4	Research
SB3	Pharmacology and molecular biology	9	Research
SB4	Computer science	5	Research
SB5	Molecular biology	10	Research
SB6	Science policy	8	Research
SB7	Theoretical physics	10	Research
SB8	Biology	8	Commercial
SB9	Biology	8	Commercial
SB10	Bioengineering	8	Research

[2] One coder had a background in computer science and complexity science; one coder had a background in mechanical engineering and engineering design. We report on the backgrounds to increase the transparency of the methods used. Qualitative inductive methods are interpretive by nature, and other analysts (from the same or other backgrounds) might arrive at different interpretations.

Descriptions of Complex Design Practice

From analysing participants' descriptions of their work, we identified three distinct aspects of complex design practice:

- ***Characterizations of complexity***—the ways in which complexity is identified, considered, and represented (e.g. unpredictability, emergence, incomplete understanding)
- ***Design objectives***—the goals that are adopted with respect to complexity (e.g. avoiding it, exploiting it)
- ***Design approaches***—the methods that are employed to realize the design objectives (e.g. simplifying the problem, experimentation, exhaustive search for solution)

Each of these aspects of complex design practice is detailed in the sections below, accompanied by select quotations from the participants.

Characterizations of Complexity

When the participants described the complexity of the systems they were concerned with, they did not characterize this complexity as a single well-defined issue. Instead, they characterized complexity in different ways, each emphasizing different features of a complex design problem. In total, 11 distinct characterizations could be discriminated, each of which is outlined below.

- **Unpredictability** is where behaviour of the system elements or the system itself is not completely predictable. For example, the system may not operate as expected, even if those expectations are held by an expert: "The thing about biology is that you have to get used to things not working on a daily basis, so it [the designed system] doesn't work most of the time" (SB5).
- **Context dependency** is where elements behave differently depending on which other elements they are interacting with. For example, a biological device working in one type of environment but not in a different type of environment: "What might work in one cell type or with one pathway or one environment or context won't work in another" (SB7).
- **Noise** is where functionally significant behaviours are only being partially realized or failing to be realized due to relatively small disruptions. For example, a few molecules might prevent the system from functioning as expected: "You've got to actually treat it as a small group of molecules with a large amount of noise in their behaviour" (SB5).
- **Emergence** is where properties of the system are non-trivially related to the properties of the elements. For example, interactions between biological entities give rise to the system's ability to reproduce or maintain energy balance in a particular environment: "You have all the different components and then under

this equilibrium condition they come together and collectively exhibit these [certain] properties and then a system has a certain number of properties, say, the ability to divide into offspring, into daughter cells, it can maintain energy balance, and we call it a living system" (SB7).

- **Stochasticity** is where behaviour of the system's elements or the system itself is probabilistic. For example, disruptions to the system can occur randomly: "The stochastic noise of the system is much higher so it becomes more of a statistical science" (SB10).
- **Nonlinearity** is where small causes result in disproportionately large effects (or vice versa). For example, a given size of input can result in a disproportionately large output: "If you are deterministic and linear, when you double the input to your system, you double the output; when you triple the input, you triple the output, that's it. With non-linear, it's nothing like that!" (SB1).
- **Crosstalk** is where there are many interactions between elements and they may interfere with each other. For example, multiple interactions can result in non-straightforward mappings between inputs and outputs: "... there doesn't have to be a neat mapping from the input to the output. It can be tangled up and hidden in all the weighted interactions between the nodes, and I'm afraid that an awful lot of biology is like that" (SB5).
- **Open systems** characterizations are those with system boundaries that are in flux with the "environment," and elements can appear to be (at the same time) part of the system and part of that system's environment. For example, feedback loops can be partially open to the environment: "... most metabolic pathways in cells are genetically regulated in a feedback structure that involves some open structures..." (SB1).
- **Overlapping hierarchies** are characterizations in which elements can be described at different levels when considered in the context of different systems. For example, molecules can belong to different "devices" or systems and hence interact with other molecules of which they are supposed to be independent, resulting in non-encapsulation: "The idea on which iGEM is based, this Lego building block idea that you can take individual components, abstract them into devices and abstract those into systems and you don't have to worry about how things are being implemented at the level of individual molecules so that you can just design at the system level… this idea that you can form such an abstraction hierarchy is just flawed" (SB5).
- **Incomplete understanding** is where the system's properties, behaviour, and/or structure is not fully characterized with respect to the required functions. For example, there may not be a complete understanding of the system's elements: "The biggest problem that we encounter is that a lot of the modules we do use are either not terribly well-characterised or not even terribly well understood. It's like trying to engineer what's inside a black box..." (SB10).
- **Multiple characterizations** of the system can mean that the relationships between different representations, descriptions, or models of the system are not fully understood. For example, the relationships between the different models of a given system may not be well-characterized even though they overlap: "We

build models for design, for analysis or for computational simulations which are numerically accurate. Most of the time, these three aspects are individual models, although they may overlap...” (SB1).

The characterizations of complexity summarized above were also recognized as being related to each other and hence should not be regarded as mutually exclusive or exhaustive. Participants’ choice of which ones to include in their descriptions was likely to have been driven by the issues that were most salient to the stakeholders and other designers working on the problem, e.g. trying to get a particular output from the system reliably, which requires predictability, while knowing that there are many interactions that might prevent this.

Design Objectives

In describing their design challenges, the participants not only characterized complexity in different ways, they also expressed different attitudes towards that complexity. This resulted in them holding different design objectives. Broadly speaking, three kinds of design objectives could be distinguished, as outlined below.

- **Design to avoid** complexity effects. For example, elements can serve to prevent interference between other components: “The ribozymes are insulators and so we’ve started using those a lot” (SB10).
- **Design to compensate for** complexity effects. For example, additional interactions can be built in to compensate for the effects of other interactions: “ok, instead of engineering, perhaps we can predict what this interaction will be by looking at the sequence. Rather than removing the context dependency, you can have a biological model that tells you what the context dependency will be so that you can account for it when you engineer” (SB3).
- **Design to exploit** complexity effects:
  - **For performance** (or efficiency). For example, the fact that a biological entity or process can serve multiple functions at the same time can be leveraged to make the system more compact or efficient: “[in electrical engineering] when current flows into one wire there is no impact on the other wire… If we didn’t have this constraint, we could miniaturise [electrical systems] a lot more” (SB1).
  - **For robustness**. For example, cooperative interactions might be encouraged so that the elements mutually sustain each other (co-dependency) and hence the system: “... one of the interesting things going forward is when people come up with better toolkits of parts that are more reproducibly different and people start to learn how to make a group of cells co-dependent and therefore exist together” (SB5).

These design objectives outlined above are by no means mutually exclusive as participants sometimes adopted more than one objective and some participants did not mention design objectives at all. Indeed, for a given design problem, it might well be that one design objective is taken with respect to complexity effects in one part of the system (e.g. trying to avoid unwanted interactions), while another objective is taken with respect to another part of the system (e.g. trying to exploit interactions to give rise to desirable higher-level properties).

Design Approaches

The different design objectives that participants held were realized in different ways by applying different methods which reflected different design approaches. These approaches can be broadly classified as "rational" or "black box," but further distinctions can be made within these broad categories, as outlined below.

- **Rational design** approaches include:
  - **Applying simplifying principles** that might allow complexity to be "rationalized" for certain aspects of the system or subsystems. For example, key factors determining system behaviour may be identified, while others are ignored: "The trick, what makes or breaks a study, is deciding which details to keep and which to get rid of…. experience has shown that there are some details that you can ignore if you want to study certain properties" (SB7).
  - **Learning through designing** and making experimentation integral to the process of designing or constructing the system. For example, biological devices might be tested in different contexts to get a better understanding of the interactions between system elements: "…that's something that you would describe as systems biology, where you're trying to take a system and understand it, but it's relevant to Synthetic Biology because in any biological system we have incomplete knowledge of the host system" (SB5).
  - **Integrating multiple characterizations** so that information about the system and its elements from different sources (possibly also from different domains) about the system are integrated and can be searched when designing. For example, computational tools can be used to exhaustively search digitally stored information about a system and identify a set of designs that fulfil certain constraints: "They've developed a computer program that takes as inputs the circuit you want to build and the input and output ranges for the sensors serve as inputs to the system, and the computer program will then search through the library of transcription factors that we've characterised and assign them based on the logic and behaviour of the sensors and the other transcription factors. It'll basically rationally engineer the system for you" (SB10).
- **Black box** design approaches include:
  - Adaptive design with *well-defined requirements*, often expressed as quantitative constraints or parameter ranges. For example, machine learning techniques might be used to find designs that achieve optimal levels of certain

chemicals: "Now if you pose the problem in reinforcement learning terms, where there are certain things you can measure in the blood which are your output, and your input is the drugs you put into the system, you can ask the reinforcement learning algorithm to optimise a certain parameter that is linked to the desired health status" (SB1).
- Adaptive design with *poorly defined requirements*, often expressed as high-level qualitative design requirements, which might themselves be highly context dependent or subject to change. For example, directed evolution can be used to find designs that work well in a particular environment: "... we can try to start doing directed evolution, where we make random mutants in the system and hope that the performance of the system improves. And if that's the case, then we just go with that" (SB10).

The distinction between "well-defined requirements" and "poorly defined requirements" is really a matter of degree rather than of kind. In the case of "well-defined requirements," it is clear what the goals of design are (e.g. maximize speed). In the case of "poorly defined requirements," they are expressed more vaguely (e.g. improve quality), dependent on multiple properties of the system (e.g. increase robustness), or subject to change depending on the environment (e.g. satisfy customer). As with the different design objectives, some participants adopted more than one of these approaches and even combined both "rational design" and "black box" approaches.

Combining the three aspects of complex design described above into a single framework, complex design can be represented as a set of related activities rather than a single type of activity. Complex design activities involve constructing a certain characterization of complexity, adopting a certain objective with respect to that complexity, and exercising a certain design approach with respect to that objective. By having a domain-neutral representation of complex design problems, it becomes possible to identify commonalities between problems that at first sight appear unrelated, and hence share knowledge, insights, and methods.

Illustration with Designing Out Crime

In order to demonstrate how the framework we have developed from our study might be applied in a different domain, we describe a scenario in which design interventions have socio-behavioural implications.

Returning to the example mentioned earlier, of designing street lighting so as to reduce crime, we can imagine two stakeholders with very different backgrounds. Stakeholder X is the budget holder for a city planning department with expertise in designing built environments that encourage or discourage certain types of behaviour. Stakeholder Y is a practising social worker with a background in social psychology. When X and Y look at the issue of street lighting, they might both describe it as a "complex" problem. For X, the *characterization of complexity* might be in terms of *unpredictability*, in that although introducing more street lighting in some cities leads to a reduction in crime, there are others in which it leads to an increase in crime. X may also characterize the project of implementing street lighting as complex due to the *crosstalk* involved in commissioning, installing, and maintaining the street-lighting regime, with different contractors and suppliers having different dependencies with each other. However, stakeholder Y might have a more explicit model of this "complexity" that takes into account the ***context dependency*** *of individuals' behaviour*. In Y's model, improved street lighting might diminish criminal activity when the area is densely populated due to potential offenders feeling "watched" but increase criminal activity in sparsely populated areas since vulnerable individuals are more visible. Stakeholder Y might also hold models that take into account individual differences, where "complexity" results from different individuals being affected in different ways by different environmental factors. Considering both social psychological and individual difference perspectives also makes Y's account a characterization that involves *overlapping hierarchies*; lighting might both encourage criminal activity in specific individuals and reduce the overall crime rate.

Due to their different domains of expertise, resources, and pressures, X and Y might have different *design objectives* with respect to the complexity they see. Stakeholder X might believe that taking into account individual differences is a waste of time and seek to *avoid complexity* by favouring a simple street-lighting solution that reduces the overall crime rate without considering all the factors that influence particular cases. As such, the *design approach* that X is taking can be said to be a *black box* approach with respect to individual differences. On the other hand, Y might argue for a *design objective* that *exploits complexity* by leveraging the relationships between community members in different lighting conditions and hence favouring a more sophisticated solution with different lighting levels in different areas. Compared to X's approach, Y is taking more of a *rational design* approach with respect to individuals' behaviours, incorporating knowledge of people's propensities to commit crime under different conditions.

In situations where resources are limited, it is often necessary to develop solutions that draw from different approaches in order to balance the costs and benefits of each. To do this, different stakeholders need to be able to talk to each other in a way that explicitly addresses each of their concerns. For example, Y might be able to encourage X to consider a more costly solution that takes into account individual differences by pointing out that this leads to a more robust situation in the long run because the crime rate is reduced even further, overall. Stakeholder Y would only be able to do this by recognizing that X is characterizing the "complexity" of the situation differently and by explicitly requesting that a different design objective is adopted (exploiting rather than avoiding complexity) and a different design approach is applied (rational design rather than black box). As we hope this example has shown, in order to have such conversations, it is useful to have a framework for structuring the concepts and language used.

Summary and Conclusions

Through structured interviews with researchers and practitioners working in the applied design field of Synthetic Biology, we inductively derived a framework for characterizing complex design practice in different design contexts. The framework consists of three dimensions, each corresponding to a different aspect of the descriptions practitioners gave of the practices they adopted in tackling complex design problems.

- The *characterization of complexity*:
  - Unpredictability
  - Context dependency
  - Noise
  - Emergence
  - Stochasticity
  - Nonlinearity
  - Crosstalk
  - Open systems
  - Overlapping hierarchies
  - Incomplete understanding
  - Multiple characterizations
- The *design objective* with respect to the complexity:
  - Design to avoid complexity
  - Design to compensate for complexity
  - Design to exploit (for performance or robustness) complexity
- The *design approach* adopted:
  - Rational design approaches
  - Black box approaches

Although the framework was derived from a study focused on Synthetic Biology, it is also useful for describing other complex design practices and the perspectives that inform those practices. In particular, complex design contexts might be compared to each other by using the same framework to describe each of them (Chen & Crilly, 2016a). These contexts need not just be technical, however, as the framework can also be used to describe social or sociotechnical design, such as policy formation and healthcare reform. We illustrated this with the "designing out crime" example, demonstrating how the framework can be used to meaningfully capture problem framing, design responses, and design activities in a domain-neutral way.

The elements of the framework are neither exhaustive nor mutually exclusive and hence should not be seen to offer a "final" means of describing complex design practice. Rather, the framework provides a structured way of highlighting the important aspects of such descriptions. Indeed, which elements are included under each of the framework dimensions might be decided "on the fly," depending on the design contexts under consideration. This allows knowledge and experience to be shared between different problems with common characteristics and also allows disparities between superficially similar problems to be identified. It is only through recognizing such commonalities and disparities that designers and stakeholders of complex design challenges can truly engage with each other and work coherently towards shared goals.

A longer-term endeavour would be to relate the similarities and differences between different design practices to their other features or to characteristics of the individuals involved. For example, we might identify trends in the way practices and problems are described and the degree to which they are social, technical, or biological (etc.); the number of stakeholders they involve; how much conflict there is between the goals assigned to the subsystems; how experienced the designers are; or how familiar the designers are with systems concepts. Obtaining such higher-level insights would lead to even deeper levels of engagement between those working in and on complex design problems. This in turn would lead to better coordinated efforts to improve design practice with respect to these problems.

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Inclusive Systemic Design for Health System Flourishment

Peter Pennefather, Katie Seaborn, and Deborah I. Fels

Abstract Flourishment is conceptualized as an engagement experience associated with eudaimonic flourishing, a component of psychological wellbeing. Analogous to nourishment, flourishment drives a sense of being one's authentic best self (eudaimonia) in a way that can be deliberately encouraged and registered within health systems, and their records, by design. Here, frameworks of social neuroscience, social fields, and inclusive human-centred design are elaborated into a framework synthesis for guiding systemic design of a system for registering evidence of patient experienced flourishment. Systemic design considerations are described for a registry of personal records of eudaimonic flourishment and enhanced resilience (PREFER). These are illustrated through description of patient engagement with the suggested PREFER registry elements. Their use in promoting a virtuous cycle of flourishment transactions within a system of patient-centred collaborative care for a person living with chronic pain is described.

Introduction

From a Hellenic perspective, hedonia is conceptualized as avoidance of pain and pursuit of pleasure, while eudaimonia is associated with the pursuit of one's best self (i.e. one's *daemon* or true spirit) towards living a flourishing life. Seaborn, Pennefather, and Fels (2015) have suggested that technology and systems designed for human use in pursuing the "good life" should consider eudaimonic flourishing as well as hedonic pleasure as design goals, along with more traditional ergonomic human factors of usability, functionality, and safety. This chapter elaborates a

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conceptual framework synthesis for guiding systemic design of a patient-centred registry for monitoring the capacity of systems of collaborative care to promote eudaimonic flourishing in the presence of chronic health conditions.

The concept of a psychological trait of eudaimonic flourishing has been elaborated by positivist psychologists, particularly Waterman (Waterman et al., 2010), coming from the perspective of personal expressiveness, and Keyes (2002), coming from the perspective of mental health. Their focus has been to develop strategies for measuring eudaimonic flourishing using questionnaires and psychological trait scales that can be correlated with other measures of mental wellbeing. The experience and expression of eudaimonic flourishing is recognized as being integrally related to an overall experience of psychological wellbeing (Keyes, 2002; Seaborn et al., 2015).

For the last 70 years, health promoted by healthcare systems has been conceptualized as not just the absence of disease but also as a state of complete physical, mental, and social wellbeing (Huber et al., 2011). That concept has been criticized as being difficult to specify and design for. Accordingly, more limited operational descriptions, such as wellness and resilience, have been advanced as the essence of health (Huber et al., 2011). However, given the important psychological dimensions of this construct, we propose that person-oriented reports of experienced enhancement of eudaimonic flourishing and/or resilience, resulting from provision of healthcare services, can be recorded and registered in a manner that can guide system governance and programmes of quality improvement. For that recording and registration to be accurate and useful, the patient has to be engaged in reporting their experiences of flourishment.

The promise and failures of health record systems illustrate the challenge of designing solutions for needs that cannot easily be anticipated beforehand (Taha, Czaja, Sharit, & Morrow, 2013). More recently, patient ownership of personal health data has been discussed as an opportunity, and possibly a necessity, for achieving the full promise of modern medicine (Shachak & Jadad, 2010; Kish & Topol, 2015). Using the concept of user-controlled and user-owned nourishment records or diaries as an analogy, patients could also register evidence of a cycle of eudaimonic flourishment resulting from health system outputs. From patients' perspective, those outputs need to be perceived and recorded as affording flourishment. If that experience can be registered by patients in a distributed manner, then it would be possible to integrate such data as transactional evidence for guiding system governance and to link that data to care procedures represented within official electronic medical records (EMRs).

With the goal of specifying the design of a registry of personal records for assisting patients and their care providers in monitoring and managing flourishment, the specific case of someone living with a chronic health condition like chronic pain is considered. The systemic design goal is to create a registry of flourishment records useful in documenting a person's eudaimonic struggle to live a flourishing life despite episodic health challenges associated with their chronic condition.

The desired functionality of this registry is illustrated with scenarios based on the case of a persona, Ms. X, a grandmother living with a complex and episodically painful chronic arthritic condition, and is representative of a large class of people living with chronic pain. The designs are anchored on a conceptual flourishment cycle involving definable terms of individuated perceptions of worldview warrants, meaning-in-care, flourishing consequences, and recruitment of brain network/mental activity systems associated with making sense of the chronic conditions and the person's health-seeking activities. In the next section, a series of concepts are specified and then synthesized into the conceptual framework.

Framework Synthesis

A Transactional Sensemaking Perspective

There are important overlaps between the concepts of psychological wellbeing, resilience, and flourishing (Ryff, 2013). This suggests that a focus on flourishing as a systemic design goal for healthcare systems is a useful avenue to explore. Both psychological flourishing and resilience are descriptive outputs of underlying mental and physical states resulting from interaction with the system ecology in which the person exists. They are also both interaction outputs of how those persons experience their healthcare options and the healthcare services that they can access. As healthcare becomes more social, in the sense of embracing a collaborative care model (Rundell, 2017), it becomes imperative to register not just actions and interactions but also orientations and transactions, within the social fields in which the actions and interactions occur (Depeltau, 2015).

A capacity to make sense of flourishment transactions within the system of care experienced by a health system user will be accentuated by designed affordances within that system. Still and Dark (2013) and Norman (1988) have discussed how technology and system features can be designed to be explicitly or tacitly perceived as affordances that afford certain outputs or consequences, by providing signals to the user about opportunities that can accrue through engagement with those features. Those affordance signals, and transactional engagement with those signals, may also be considered a form of evidence when they are registered and linked to completed process episode transactions within an evidence-based health system designed to achieve health-related goals through prescribed transactions.

Drawing upon insights from frameworks of (1) social neuroscience, (2) social field theory, and (3) inclusive human-centred design, we propose a sensemaking synthesis of frameworks for guiding health system design. The aim is to ensure that the patient perspective is evident in record systems guiding their care. In keeping with the classical origins of the concept of eudaimonia, these three frameworks roughly parallel classical thinking about how people make sense of the world. Over two millennia ago, Aristotle theorized that engagement with making sense of our social transactions in the world was driven by three distinct types of conscious mental activities. Those mental activities were characterized as having two complementary attributes: their essential nature and their consequences. For example, the activity

Table 1 Multidimensional sensemaking of warrants and meanings

Brain network	Warrant (perspective) meaning	Aristotelian activities		
		Essence	↔	Effects
Salience	Empowerment (systemic-scholarly) coherence	Theoria/ theorizing	↔	Episteme/science
Executive control	Agency (business-professional) purpose	Praxis/acting	↔	Phronesis/ judgement
Default	Engagement (socio-cultural) significance	Poiesis/creating	↔	Techne/proficiency

of theorizing (theoria) can lead to skill in the performance of science (episteme). Two other dimensions were also invoked: the poiesis-techne (making and proficiency) and phronesis-praxis (acting and judgement) dimensions (see Ramo, 2004).

A social neuroscience framework explains how the mental activity involved in making sense of, and interacting with, the social world of any collaborative activity is mediated by large-scale brain networks integrating emotional, social, and cognitive phenomena associated with that social activity and increasingly accessible to direct monitoring and empirical characterization (Barrett & Satpute, 2013). Those networks emerge from rationalizations of patterns recognized through observations made throughout recorded history. Here we equate the social neuroscience framework as reflecting primarily a theoria-episteme axis as insight derived from that framework reflects a more systemic-scholarly perspective. It tends to favour activity of the salience network. In terms of sensemaking, this perspective aligns with the idea of enactive sensemaking. Enactive sensemaking is defined as a subjective act resulting from the interaction between (a) observable actions, activities, and experiences involved in autonomous engagement with life and society, and (b) the cognitive processes involved in rationalizing and making sense of decision options arising with/from those experiences (Thompson & Stapleton, 2009).

A human factors engineering framework informs the practice of using a scientific understanding of the physical and psychological characteristics of people to guide the design of technology and systems for human use (Woodson, Tillman, & Tillman, 1992). Inclusive design considers a wide variety of possible users from the beginning of the process and allows for customizable solutions (Newell et al., 2011). It can be equated with the phronesis-praxis dimension of mental activity reflecting a rules-based business-professional perspective on sensemaking. This rules-based sensemaking can be operationalized within organizations (see Weick et al., 2005). In contrast, a social fields framework (Depeltau, 2015) reflects poiesis-techne axis thinking. This can be associated with the default brain network and a socio-cultural perspective that can be related to the person-oriented sensemaking methodology of Dervin (2015). This synthesis is summarized in Table 1.

Inclusive Eudaimonic Systemic Design Framing of Flourishment Cycle Specifications

Systemic design is considered to be a "strong systemic view of complex system problems addressable by intuitive and abductive approaches implicit in design thinking" (Jones, 2014a, p. 92). Hence, inclusive eudaimonic systemic design will necessarily deal with the complex systemic process influencing how diverse worldviews impact how people make sense of the highly regulated and registered world of healthcare transactions. Designs concerning systemic flourishment aims, goals, and objectives need to consider how to measure and promote the eudaimonic flourishing trait that the systemic flourishment inputs seek to elicit. The goal is to represent and register those inputs within health system records so that this personalized input-output transaction can be measured, analysed, and understood as influenced by a dynamic system of actions, interactions, and transactions among structures, processes, and outputs. This representation then can guide health system outputs in determining individuated eudaimonic flourishing.

While a patient-oriented registry of flourishment inputs that aims to track and promote flourishment can be designed for a variety of end users, people living with chronic pain may be a particularly appropriate user group to explore within a flourishment design framework. Such a framing needs to incorporate design considerations and goals, and organize them around experiences reported by individuated persons. A focus on individuated eudaimonic flourishing is considered because health systems are often designed, implicitly or explicitly, to meet some specific set of purposes or goals dictated at a system level and constrained by always-limited resources. Because those systems are rarely simple and are often complicated and complex, there can be disconnects between the intent of the system and the experience of people using the system. That disconnect may cause individuated frustrations that will interfere with the capacity of the frustrated user of the health system to live a flourishing life.

Hancock, Pepe, and Murphy (2005) have proposed a framework of hedonic, or "pleasure-seeking," design, which they called *hedonomics.* Key to this model was the notion of "additive design." Unlike traditional human factors, which focused on avoiding or eliminating undesirable states in the end user, hedonomics proposed a focus on adding value to individuated end-user experience, particularly through pleasurable components. Seaborn et al. (2015) went on to propose *eudaimonics* as an ergonomic framework for human factors research that extends the hedonomics model by explicitly considering eudaimonic factors. The extended model has three components: ergonomic factors (safety, functionality, and usability), hedonomic factors (usability and positive affect), and eudaimonic factors (sensemaking and flourishing affect). All three orientations of the system user must be considered when designing with the aim of allowing for, creating a sense of, or co-producing flourishment in the health system user.

A eudaimonic flourishment cycle specification is represented in Fig. 1. A high-level description of that cycle starts and ends with a multidimensional sensemaking

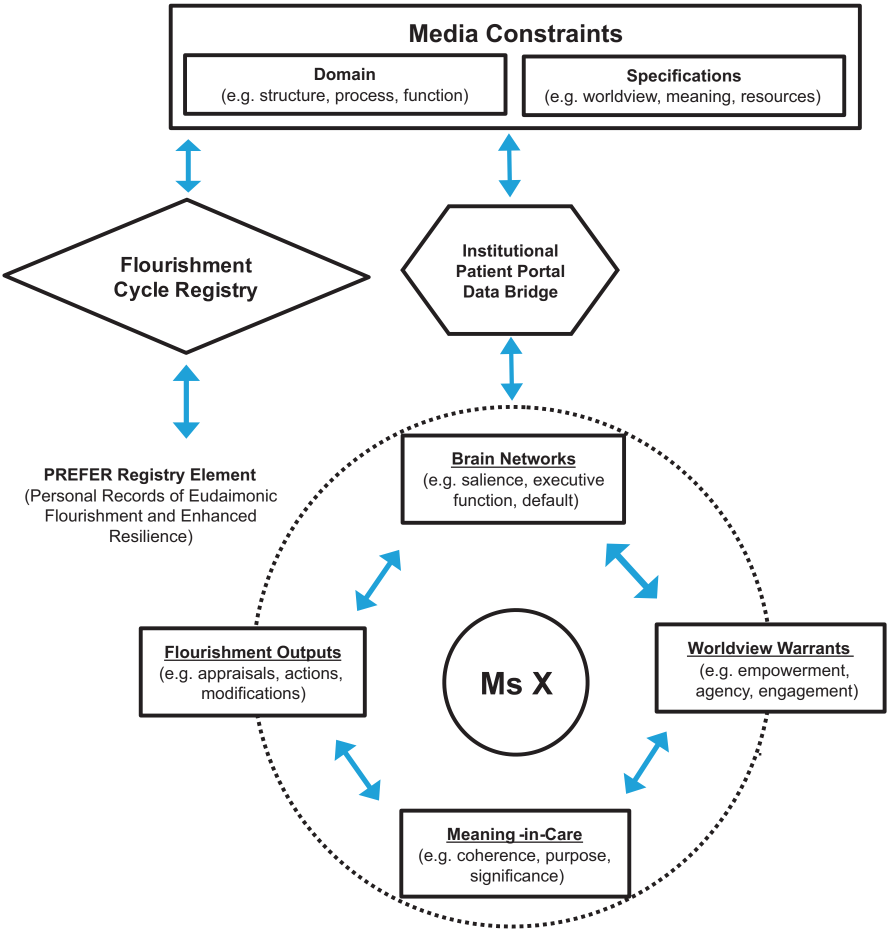

Fig. 1 Schematic representation of relationships between framework elements

process perceived first by the patient but involving many stakeholders each engaged in their own sensemaking processes. Although that patient-oriented experience can be described at many levels, here we limit our conceptualizing of the initial stage of this cycle to the activity of brain networks postulated to be engaged in the cognitive processing by the patient of their situation with respect to the collaborative care process they have elected to participate in. The cognitive processing, which ultimately drives the flourishment cycle, will be influenced by personal worldview warrants related to personally perceived empowerment, agency, and engagement that initiate and maintain a person's health-seeking actions. Systemic encouragement and legitimization of those actions will be assigned individuated meaning to the extent that they are perceived as coherent, purposeful, and significant. Together, legitimized actions and how they are meaningfully preformed and experienced will be amenable to appraisals, actions, and modifications. Those flourishful activities will contribute directly to a flourishful life and reinforce a eudaimonic orientation. In order to provide flourishment and maintain and enhance the person's homeostatic state of eudaimonic engagement, there needs to be a system of accounting or record-keeping that can be evaluated at a system level but still be informed by actual patient experiences registered in some way.

Meaningful Healthcare Worldviews Martela and Steger (2016) have published a theoretical overview of how the concept of "meaning-in-life" can be understood in three ways, all of which contribute to the experience of meaning. These are coherence-, purpose-, and significance-in-life. Meaning-in-life is motivated by a comprehensible and coherent sense of meaning in what is being achieved. That meaningfulness is derived from a future-looking sense of purpose that is often related to an overarching higher purpose. It is also derived from a capacity to make day-to-day choices that are experienced as being significant (Martela & Steger, 2016). There are a number of measures of meaning in life that can be correlated with both eudaimonia and hedonia in distinctive ways (McMahan & Reken, 2011). Therefore, it should be possible to adapt those instruments to measure meaning-in-care. By registering and visualizing those measures and the reflections they generate in a private record system, an account is created of the experienced flourishment as it happens. That account also can, in principle, be used later as evidence for documenting and improving effectiveness of the flourishment system.

A Registry of Personal Records of Eudaimonic Flourishment and Enhanced Resilience (PREFER)

If a person living with chronic pain is to be empowered to have more agency in seeking care for a chronic pain condition, questions arise regarding how to effectively achieve more patient-centredness. Kish and Topol (2015) describe how healthcare systems currently have difficulty accommodating patient input and control over records of their diagnoses and care. It is recognized that patients have the right to access and view that data. However, there is little room for patients to usefully build on those records. That deficit can be directly related to the lack of ownership of health data records by patients (Kish & Topol, 2015). A registry, pointing to private but sharable and federatable PHR entries, is imagined as a location for registering patient-generated evidence of how they make sense of their healthcare choices.

This evidence then can be linked directly to electronic medical record entries that have more instrumental meaning. Although potentially useful in and of itself, such registration allows for latter incorporation of this data into bodies of evidence assembled to evaluate outcomes within patient-centred collaborative care systems. A user-centred focus that recognizes the user's worldview and how that impacts the user's position relative to the record system may increase meaningful use (Huvila et al., 2015; Kish & Topol, 2015). The importance of understanding the person's position or worldview with respect to a technology or a design applies also to the measurement and monitoring of psychological traits like flourishing (Nilsson, 2014).

A PREFER registry, pointing to private PHR entries that can be shared with the owner's permission, could serve the role of respecting a person's worldview by aggregating a person's data related to how their healthcare experience is expected to promote personal eudaimonic flourishing and enhanced resilience. Such a system of record entries would allow comparison of expected outcomes and actual experiences in a pragmatic and transparent manner. It would do so in a way that the person's worldview, and how that warrants the user's wellbeing seeking activities, is recorded and made evident to themselves and to people around them providing support and care. This would allow system-level as well as personal-level tracking of the extent to which the healthcare system user finds meaning in the care that they are receiving for a chronic condition that is dominating their life experience.

Design goals for the PREFER registry then would include a capacity to guide (1) coherent empowerment, (2) purposeful agency, and (3) significant engagement within prescribed pain management plans. The purpose of making entries into the record would be to allow the person living with pain, as well as their circle of care, to make sense of flourishment signals. Those entries should be constructed and shared in a way that makes the person's worldview evident in the health record, implementing the principle of "nothing about us without us" (Charlton, 1998).

Brain Networks Involved in Appreciating Flourishment Transactions At a fundamental level, brain networks influence the cognitive work that the mind needs to invoke in order to process emotional, social, and cognitive signals. For a person like Ms. X, who is living with chronic pain, this will be dominated by a need to find meaning-in-care through, for example, appraisal of how that care is salutogenic, guiding resilient responses to care setbacks and rumination concerning how to modify care plans to better suit needs and desired wellbeing outcomes. The factors that enable a capacity for finding that meaning-in-care combined with factors that warrant autonomy will lead to flourishment outputs that are experienced by Ms. X, but which are also documentable and measurable using tools accessible from the PHR platform. Reflective appraisal of those observable and experienced outputs could also allow for further sensemaking by Ms. X and others involved in her life, creating a virtuous flourishment cycle.

Let us look in greater detail at the elements driving the postulated flourishment sensemaking cycle. The cycle begins with consideration of three main cognition networks for processing emotional, cognitive, and social inputs: salience, default, and executive function networks. The salience network handles routinized sensemaking through appraisal and weighting of the importance of the multitude of salient signals encountered in everyday life. It integrates these signals into a coherent but dynamic picture of what can be neglected and what should be attended to. The default network is associated with spontaneous (or mentalized) thoughts that are self-generated within the mind and are given various levels of significance by the salience network and worked into counterfactual scenarios and mental simulations of future possible actions. The executive function network deals with integrating externally directed attention and working memory to guide decisions concerning the task within its social context (Barrett & Satpute, 2013).

From a brain network perspective, cognitive bandwidth will be limited such that processing activities must be prioritized, making recruitment of brain network resources dynamic and episodic (see Beaty, Benedek, Silvia, & Schacter, 2016; Barrett & Satpute, 2013). This parallels the episodic nature of affective influences on performance, where semi-automatic appraisal and intrinsic ruminations about the nature of those affective influences detract from the ability to deliberately carry out the task at hand (Beal, Weiss, & Barros, 2005). For Ms. X, the act of getting up from a chair, for example, may cause pain signals that remind her of her condition and all of the biopsychosocial implications of that condition. This may detract from her ability to focus on why she needed to get up in the first place.

Different warrants can influence which cognitive pathway resources are recruited and prioritized for a given information processing task. For someone living with pain, the disability that the pain causes is related to the salience of the pain signals. The word salience is used here in the operational sense of how the situation is perceived as likely to impact future survival. The experience of pain is intimately tied up with the threat perceived in the sensory signals identified as painful (Borsook, Edwards, Elman, Becerra, & Levine, 2013; Williams, 2017). Hence, pain is more of an awareness of a need state than a sensory input (Williams, 2017). The salience brain network involved is associated with a person's ability to recognize and analyse events that are dangerous for the body's integrity. The salience network overlaps with networks involved in sensory-motor and emotional-introspection integration (Cauda et al., 2012).

As a result, the propensity of the brain to direct limited resources to focus on responding to pain signals will be dependent on a person's mental worldview and sense of meaning-in-care that allow them to evaluate the context in which the episodic pain is experienced. Indeed, recent studies suggest that for people with a similar diagnosis of the origin of the pain, those who score higher on a meaning-in-life scale will score lower on scales measuring pain intensity (Richardson & Morley, 2015). This effect may also explain how mindful dispositions and interventions aimed at pain acceptance reduce the experience of pain (Veehof, Trompetter, Bohlmeijer, & Schreurs, 2016). A focus on mindfulness and acceptance interventions, and on tracking their impact within the context of a PREFER registry, can provide a window of effectiveness of system affordances that promote flourishment.

PREFER Registry Design Elements

Multidimensional Sensemaking of Warrants and Meanings This conceptual framework compares and synthesizes what Aristotelian philosophy proposed was involved when people made sense of the world and what modern neuroscience experimentation has revealed. Table 1 considers three types of information processing warrants and meanings and proposes respective linkages to brain networks that are likely to be primarily involved in sensemaking: salience, executive function, and default. We further link those to the theoria-episteme, phronesis-praxis, and poiesis-techne dimensions of Hellenic philosophy (Ramo, 2004) via three equivalent domains of social activity perspectives: systemic-scholarly, business-professional, and socio-cultural. This rather idiosyncratic approach is not intended to dismiss the evolution of thought that has occurred since the days of classical Hellenic debates (see Ing, 2013; Jones, 2014b). Rather the intent here is to recognize that sensemaking has long been considered multidimensional in that it adapts to the transactional social field sensed by the person (Depeltau, 2015).

Starting with the salience network, one can imagine that it has an important role to play when a person feels warranted to empower themselves by seeking relevant information about their condition(s). For example, consider the persona of Ms. X who suffers from rheumatoid arthritis and is worried that the task of navigating her three-storey house will be a challenge when her grandchildren come for a long-planned visit. She can take on a systemic-scholarly perspective, where she seeks meaning through a coherent integration of the information available to her so that she can judge what is possible to do about the challenge of climbing stairs. She may experiment with different paces at different times, assigning different values to the signals according to what she has read or heard. She may imagine different scenarios and search the Internet for different options. That perceived warrant to modify her behaviour and the meaning assigned to that activity can be linked to a theoria-episteme mental activity axis.

The executive function network will be preferentially engaged with a business-professional perspective through which courses of actions that the person feels they have agency to pursue will be pursued with a sense of purpose. Through her research and literacy development, Ms. X has discovered the difference between an occupational therapist and a physiotherapist and sets out to work out a plan to identify and pay an appropriate rehabilitative therapist to provide advice and support in navigating the stairs in her house while her grandchildren are visiting. She may even operationalize a rehabilitation plan co-created with the identified therapist and make decisions such that the plan is carried out in time, leading to satisfactory progress. That business-professional perspective can be linked to a praxis-phronesis mental activity axis that recognizes the link between the acting out of specified roles and the demonstration of judgement in the choices made.

The default network will be engaged when a more ecological socio-cultural perspective is required of the person. A person living with pain will need to seek meaning in significant acts. That significance can emerge from insightful means of sharing and valorizing ideas about socio-cultural options, risks, and opportunities to develop insight into socially appropriate behaviour. For example, Ms. X may be afraid of the stigma associated with admitting to others that her chronic pain condition is interfering with her ability to navigate around her house. Most of the time, she is fine, but she is worried that her children and grandchildren will judge her incompetence when they come for an extended visit. However, by drawing upon cultural narratives, and interacting with appropriate mentors, she may develop insights into how to reimagine her life with the pain and to overcome a fear of stigma. That insightful priority and socio-cultural perspective can be linked to the poiesis-techne mental activity axis that recognizes the link between a creative decision to reimagine a person's situation and the proficiency with which that sense-making process is carried out.

Flourishment Cycle Element A schematic representation of how distinct facets of the flourishment design framework can be organized and applied was presented in Fig. 1 and is further discussed here in greater detail. There are several interacting record systems represented: the institutional EMR system that tracks the health system transactions it mediates, Ms. X's PHR linked to a PREFER registry, a patient portal domain served by the institutional EMR that allows Ms. X to copy entries from the official EMR to her PHR, and a system of record entries used by people responsible for ensuring that health system transactions are conducive to eudaimonic flourishment. Each different shape refers to a different type of design consideration related to components of interacting record systems. The boxes reflect domains that can be represented by record entries. The diamond refers to the flourishment framework developed for the particular case of supporting the process of bridging the institutional record of Ms. X's healthcare with a PHR record of that care owned by Ms. X. That framework will be adapted and elaborated through consideration of entries that enable systematic reflective analysis of the system usability. The circle refers to interacting fields of entries within the PREFER domain of Ms. X's PHR. The boxes inside the circle refer to measurements and assessments that are reliant on Ms. X's powers of reflection, although they may be augmented measurements using tools associated with the PHR. The boxes spanning the edge of the circle refer to measures and assessments that can be arrived at by Ms. X and people observing Ms. X.

The framework begins with characterizing dimensions of the media system under consideration. Most institutional EMRs now include a patient portal option (see Irizarry, De Vito Dabbs, & Curran, 2015). The framework draws the designer's attention to different dimensions of the media design challenge. For example, the designer should start by considering the system domains that will have an impact on care plan consequences. These can be considered at the structural level, the process level, or the output/function level (see Lahka et al., 2015; Ing, 2013). The designer should also consider design constraints such as the expected range of (1) worldview warrants that Ms. X brings to the system, (2) meanings-in-care that the media might elicit for her, and (3) resources associated with meeting her range of goals. At the next level, the designer needs to consider how to enable creation of a bridge between the institutional patient portal set up for Ms. X and personal records generated by Ms. X and organized through her PREFER registry. This data bridge would be designed to allow both a system user, like Ms. X, and system designers or administrators to record and register perceptions and commentaries associated with individuated cycles of flourishment.

The next part of the schematic diagram illustrates the different phases of the flourishment cycle supported by a PREFER registry. Information from the patient portal media will be processed first by the different networks operating within Ms.

X's brain, which will, in turn, be combined to define her experience. How she interprets that information will then be influenced by how the system accommodates her worldview warrants. The extent to which her empowerment warrant is perceived as appropriately accommodated will be dependent on her perception of the coherence of the information served by the media. The exact way that she uses her agency warranted by that information will be determined by her sense of purpose. Her engagement in executing that agency will be dependent on how significant she finds the information. The combination of worldview warrants and meaning-in-care derived from executing those warrants will allow Ms. X to experience and exhibit flourishment outputs such as reflective appraisals that are salutogenic, considered actions that are resilient, and self-initiated modifications that demonstrate judgement.

Those flourishment outputs of reflective appraisals, resilient actions, and justified modifications will be experienced by Ms. X in a way that will drive the flourishment cycle forward. This will be especially true if the media allows Ms. X to record those reflections, actions, and modifications in a way that reconsolidates the record's information content in light of those new activities, while at the same time allowing Ms. X to reconsolidate her take on how the care is progressing. This can be accompanied by direct probes of the person's effective states on the spectrum between eudaimonia and depression. At a metalevel, those entries can be anonymized and observed by the system designer who can adapt the media technology to better support individuated flourishment cycles.

Application of the Framework

Table 2 shows how the flourishment design conceptual framework illustrated in Fig. 1 and Table 1 can be joined together. To illustrate how that synthesis might work, we consider Ms. X again. Such a linkage would be mediated by a record bridge between the rehabilitation institute's patient portal account for Ms. X and a PHR built for Ms. X around emerging standards like FHIR (see Mandl, Mandel, & Kohane, 2015) with a PREFER registry extension.

Ms. X has been encouraged to participate in a mindfulness training programme organized by the rehabilitation institute that the therapist is associated with. The institute maintains an electronic medical record (EMR) system with a patient portal feature. That patient portal has been adapted to allow users to copy institutional EMR data about them to their own PHRs. This is accompanied by a locator for the data in the EMR system. The PHR has entries designed using eudaimonic flourishment principles that can be registered and linked to the official copies of the institutional EMR data entries. A PREFER registry can be designed to assist rehabilitation institute clients like Ms. X to reflect on the quality, purpose, and impact of the services that they obtain though the institute.

Scenario 1 For example, the institute sponsors a number of mindfulness and acceptance training options each with a number of trainers. At the level of the infor-

Table 2 Scenario-driven illustration of steps in flourishment cycle for Ms. X

Scenario (level)	Media priority	System perspective	Brain network	Worldview warrant	Meaning-in-care	Flourishment output
Scenario 1 (structure)	Integration-driven assessment	Systemic-scholarly	Salience	Empowerment	Coherence	Salutogenic appraisal
Scenario 2 (process)	Legitimacy-driven implementation	Business-professional	Executive control	Agency	Purpose	Resilient action
Scenario 3 (function)	Insight-driven adaptation	Socio-cultural	Default	Engagement	Significance	User-driven modification

matics infrastructure (structural level), the patient portal allows Ms. X to register with one of those programmes and sign up for a particular session of that programme. The portal data bridge allows Ms. X to copy that information and any other related information she deems relevant to her PHR. Through the PREFER registry, she would be used to track and coordinate transactions within those programmes in ways that create meaning within the healthcare system at both personal and public levels (Shachak & Jadad, 2010). That sensemaking will be enhanced if Ms. X, or someone she trusts, can adopt a systemic perspective. That perspective could be based on a belief anchored by her particular worldview that there is an integrated logic governing her care. Such a worldview, in turn, informs set-up of a system to collect data for guiding implementation of that logic. That data can be structured so that it can be interrogated in ways that are meaningfully helpful towards meeting her healthcare needs and allowing her to adapt it according to those needs.

That approach will engage the salience networks in Ms. X's brain as she searches through information concerning a mindfulness training programme online through the portal or as she uses her preferred search engine for programmes that she is comfortable with. The salience network will also be engaged when recording and reflecting upon signals from her interactions with the chosen programme. Provided that Ms. X is empowered to interrogate her record through, for example, plain language descriptors and resources available to help her use the record data meaningfully, she may then be able to develop a sense of coherence about her progress with the mindfulness development programme that can allow her to appraise how that intervention can help her meet her episodic goal of enjoying her grandchildren's visit, that is, to determine whether the programme is salutogenic.

Scenario 2 At the process level, the mindfulness training programme will be supported by media that legitimize the professional and business transactions necessary to engage with that programme. Information organized in that part of the record system will be processed through Ms. X's executive control network. From the worldview warrant perspective, agency on Ms. X's part will allow her to participate actively in making decisions about which mindfulness trainer they will interact with. This will require that she understands the purpose of the programme and the credentials of the people delivering the programme, which in turn will allow her to anticipate how diligent she needs to be in order to meet her goals. These decisions may require resilience on her part to deal with setbacks or changes in the programme delivery context.

Scenario 3 At the output level, Ms. X needs to figure out how to carry out her mindfulness exercises outside of the institutional training setting and in the setting where she lives. However, because of her socio-cultural values, Ms. X may need to adapt the training programme to match her worldview and its influences on her personality and values, and those of the people she associates with. Insight and creativity emerges from operation of the default pathway (Beaty et al., 2016). This will help Ms. X remain engaged with the programme and feel that the exercise has significance. That feeling of significance may motivate her to engage in user-driven modifications in the self-managed mindfulness and acceptance programme.

Conclusion

The model of flourishment design that we have proposed is an initial effort towards providing designers, practitioners, researchers, and end users—the people living with chronic conditions—with an actionable, understandable framework of a complicated and often overwhelming system. The framework synthesis can serve as a guide for designing features such as PHR elements linked to a PREFER registry that allows users to engage in actions that result in eudaimonic flourishing. Those flourishment features promote a virtuous cycle. It will be important, however, to ensure meaningful patient engagement. Simply including patient-reported outcome fields in an EMR does not appear to affect pain care results (Harle et al., 2016).

Participants in a patient-centred healthcare system must have empowerment, agency, and engagement to actively participate in such a system. They must find coherence, purpose, and significance in that participation. For that participation to be perceived as flourishing, it must be associated with personal appraisals, actions, and modifications to the care programme that are perceived by the participant as improving and promoting a flourishful life. The perception will be dependent on mental activity emerging from the operations of brain networks. Many of the elements underlying the proposed flourishment cycle now can be monitored using validated measurement methodologies that can allow users to track their eudaimonic flourishing progress within their care plans. These could also be used by the system to justify resource allocation for helping people living with chronic pain to live well and prosper.

Going forward, we encourage a range of interested parties to join us in designer-oriented and empirical investigations of the model within a healthcare context through an inclusive, human-centred approach—practice and research that involves and carefully considers the patient as an individual primed for flourishment. Recent advances in making sense of classically defined mental activity in terms of underlying brain network activity, and used in a media designed to highlight flourishment affordances and opportunities, may provide new avenues for the pursuit of personal and societal progress in managing episodic disabilities associated with complex chronic conditions such as chronic pain. Those patient-reported outcomes should help all system participants to reimagine and redesign healthcare options so that users can drive their care outcomes towards the helpful pole of the help-harm continuum.

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Part II
Theoretical Foundations

Systems Design Thinking: Theoretical, Methodological, and Methodical Considerations. A German Narrative

Wolfgang Jonas

Abstract The chapter presents a facet of the hidden histories of systems design. It focuses on the German development, especially the trajectories that emerged from the Heidelberg-based Studiengruppe für Systemforschung (SfS) (1958–1975). The group gathered a number of important systems researchers and contributed, at least indirectly, to the development of the author's theoretical and methodological position. System concepts are examined from a design perspective and the crucial notion of the "inquiring system" is elaborated, the latter providing the basis for dealing with the mix of facts and values inherent in design research. This sets the stage for methodological developments, especially the generic APS model of design and research processes: Analysis – Projection – Synthesis (Jonas W. Viable structures and generative tools – an approach towards 'designing designing. In: Proceedings of EAD conference, Stockholm, April, 1997a; Jonas W. N-th order design? Systemic concepts for research in advanced methodology. Submitted to *Design Issues* special issue on design research (unpublished), 1997b) and its practical implementation. Three authors will be presented in some more detail. Their approaches complement each other and provide a flexible model and toolbox for systemic design processes.

Introduction

The chapter presents a facet of the hidden histories of systems design. It focuses on the German development, especially the trajectories that emerged from the Heidelberg-based Studiengruppe für Systemforschung (SfS) (1958–1975) (see Brinckmann, 2006; Simon, 2011). The group gathered a number of important systems researchers and contributed, at least indirectly, to the development of the author's theoretical and methodological position. The latter is developed and presented in detail.

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Motivation

Current design thinking—the "management fad" (Jones, 2014), not the research programme under the same label—and mainstream design in general show a considerable lack of interest in systemic and other foundations. Nonetheless there are well-founded, albeit scattered, and often overlooked systemic design traditions. The German development path is probably one of the lesser-known contributions. Protagonists like Helmut Krauch and Horst Rittel, both associated with the Heidelberg-based SfS, as well as Frederic Vester and Siegfried Maser, have contributed to what Pourdehnad et al. (2011, 4) now call Third Generation Design, where the stakeholders are the designers. Furthermore, the integration of design thinking and systems thinking establishes essential foundations of futures-studies-based strategic design (Gausemeier, Fink, & Schlake, 1996). The following is not about human-centred design but about designing by, within, and for social systems of various kinds.

Overview

The chapter will briefly outline the development of systemic design in Germany since the 1960s. It builds on theories of first- and second-order cybernetics, complexity, and evolution. System concepts are examined from a design perspective and the crucial notion of the "inquiring system" is elaborated, the latter providing the basis for dealing with the mix of facts and values inherent in design research. This sets the stage for methodological developments, especially the generic APS model of design and research processes: Analysis – Projection – Synthesis (Jonas 1997a, 1997b) and its practical implementation. Three authors will be presented in some more detail. Their approaches complement each other and provide a flexible model and toolbox for systemic design processes:

- Vester's (1988, 1997) *sensitivity modelling* covers the Analysis phase in an interactive and collaborative ("second order") manner and provides the connection to Projection by means of simulation tools that allow for exploratory "what-if" questions.
- Schwartz (1991) focuses on the Projection phase by providing a simple but effective scenario design procedure. Vester's sensitivity modelling can ideally be applied upstream of Schwartz's method.
- Gausemeier et al.'s (1996) almost generic strategic foresight procedure supports the complete process of Analysis and Projection and provides substantiation for the final Synthesis phase.

The findings suggest that systemic design and futures studies have significant structural and procedural matches and might become productive partners. Moreover I will argue that systemic design thinking—if it finds a broader acceptance and support in both the design and the systems community—has the potential to provide the epistemological and methodological basis for what was defined as *mode-2 science* (Nowotny et al., 2001), third-phase science (De Zeeuw, 1996), *transdisciplinarity studies* (Nicolescu, 2008), and, in Germany, *transformative research* and *mode-3 science* (Schneidewind & Singer-Brodowski, 2014). For an overview, see Mielke, Vermaßen, Ellenbeck, Milan, and Jaeger (2016).

Systems Design Thinking in Germany

The SfS, which existed from 1958 until 1975, can be regarded as the main intellectual origin of systems design thinking in Germany. The group has been one of the leading advisory bodies for government and administration in the early Federal Republic of Germany. Important working areas were technology assessment and science policy planning. Founder and head Helmut Krauch (1927–2010), a chemist, social scientist, and concept artist, strongly promoted the development towards participatory approaches of science policy planning and direct democracy in formulating political long-term goals. In 1965, Krauch met C. West Churchman at the *center for the study of democratic institutions* in Santa Barbara. During a stay in Berkeley, Krauch developed the Socratic concept of "maieutic system analysis," which—in contrast to "instrumental system analysis"—considers the *Weltanschauungen* and value-based anticipations of the actors. Latent knowledge and critique should be activated through patient and skilful questioning. Moreover, the idea of a technically supported interactive exchange via mass media between politics, experts, stakeholders, and citizens, called "organized conflict," was born (see ORAKEL below).

These ideas influenced the concept of the so-called Kanzler-Informations-System, a mixed-media device, which would then provide the chancellor with selected and relevant information. In his words: "A completely trivial system" (Krauch in Der Spiegel, 1970). The screenshow was to be enriched with fictitious debates with several speakers treating a problem dialectically. By means of "Organized Representative Articulation of Critical Development Gaps" (ORAKEL), trends were to be discovered, which was to allow politicians to take unpopular measures that would be rewarded by the public in the future. This "time lapse experiment" (Krauch in Der Spiegel, 1970) "is to measure in advance what the population will understand in a couple of years." But Krauch himself, in full "counterculture" mode (Turner, 2006), doubted the feasibility of his system with the current staff at the Chancellery's (Krauch in Der Spiegel, 1970): "If you work with old-fashioned, bony lawyers, it is but a thousand difficulties." Therefore technologically inclined social researchers should be sent to the Chancellery, to then "permanently re-educate" the staff. The only ORAKEL experiment in "computer democracy" (Krauch, 1972) with real-time public participation was conducted on Krauch's own initiative, in a TV format in 1971 that used telephone polls and immediate computer evaluation of feedback.

Not only the general decline of planning euphoria in Germany since the early 1970s, but probably Krauch's uncompromising style when trying to enforce his ideas of democratic participation, contributed to the rapid shutdown of the publicly funded think-tank SfS in 1975. Already in 1973 the Federal Ministry of Research stated that the SfS had met its own demand to provide decision support for the administration only partially. Results had often not satisfied because of their lack in practical relevance; in addition there was allegedly a lack of expertise (Seefried, 2015). The current Institute for Technology Assessment and Systems Analysis (ITAS), which is part of Karlsruhe Institute of Technology (KIT), can be regarded as one of the successful offsprings of SfS.

Horst Rittel (1930–1990) has been one of the associated members of SfS. Probably Rittel's insights into the political nature and argumentative form of complex planning and design tasks have been more reflected than Krauch's missionary approaches, or his sometimes slightly arrogant attitudes. Another associate of the group has been philosopher Jürgen Habermas, whose theory of domination-free discourse (which has been criticized as naïve and too simplistic by proponents of social systems theory in Germany) has found its way into the strategies of the group.

Krauch met Frederic Vester (1925–2003) during a postdoctoral fellowship at Yale University in 1957, where both cooperated in a biochemical experiment for several months. Vester was loosely associated to the SfS since then. In 1970 he founded the private Munich-based Frederic Vester Studiengruppe für Biologie und Umwelt GmbH (Frederic Vester Study Group for Biology and Environment, Ltd.), renamed Frederic Vester GmbH (Frederic Vester, Ltd.) after his death. His ideas have strongly influenced the formation of the environmental movement and the Green Party in Germany. He was a member of the Club of Rome; his book *The Art of Interconnected Thinking* (1997) has been selected as a report to the Club of Rome.

Vester is known as a pioneer of interconnected thinking, a combination of cybernetic and systemic ideas and complexity. Central features include viewing a system as a network of interrelated effects, leading to emergent behaviour of the system as a whole. Systems can be modelled and visualized via computer software, so that even someone with the most basic understanding of networks will see relations, including positive and negative feedback loops. Simulations can help to investigate the effects of interventions into the system. The *sensitivity model* has been used since the 1980s in studies for Ford Germany (Vester, 1990), UNESCO, and many other public and private institutions. Vester sees the designer in the position of an overall systemic synthesist (Vester, 1972):

> …it is neither possible nor desirable to design a product in isolation, with no reference to its sociological, psychological, and ecological environment.
>
> It is especially in this respect that designers play a key part in future development, not because they are more intelligent, or better informed, or more creative, but because they have been accorded the role of the overall synthesist. This is a role that does not even require the power to make decisions, for it is often enough to demonstrate the interrelations and their consequences, as well as the possibilities for 'cybernetically meaningful' new products, and to make sure they are talked about. No member of another discipline could assume this role. In all areas of science and technology there is an increasing professional specialization. It is only the industrial and environmental designer who is confronted horizontally with all fields of knowledge. It is precisely these coordinators that are lacking

> today. They are in demand everywhere, as a professional group that could perhaps be accorded an even more meaningful task than before. (p. 4–9)

Krauch, Rittel, and Vester have paved the way for systems design thinking in Germany. Another key figure—although only loosely connected to the above protagonists—has been philosopher, mathematician, and physicist Siegfried Maser (1938–2016). In the 1970s he held a chair for systems research and planning theory in the department of experimental environmental design at Braunschweig University of Art. Maser's (1972) theoretical and epistemological clarifications (see section *Conclusion. Systems Design Thinking As the Model of Transdisciplinary/ Transformative Science*) provided a framework for a new "trans-classical" concept of scientific inquiry. I have complemented these German positions with two American protagonists. The following, rather personal, mapping gives an idea of the range of ethical and epistemological positions and the "flavours" of systems design thinking. It contrasts and relates C. West Churchman (1913–2004), "the thoughtful melancholic"; Herbert A. Simon (1916–2001), "the composed positivist"; Frederic Vester (1925–2003), "the friendly missionary"; and Horst Rittel (1930–1990), "the Socratic ironist" (Fig. 1).

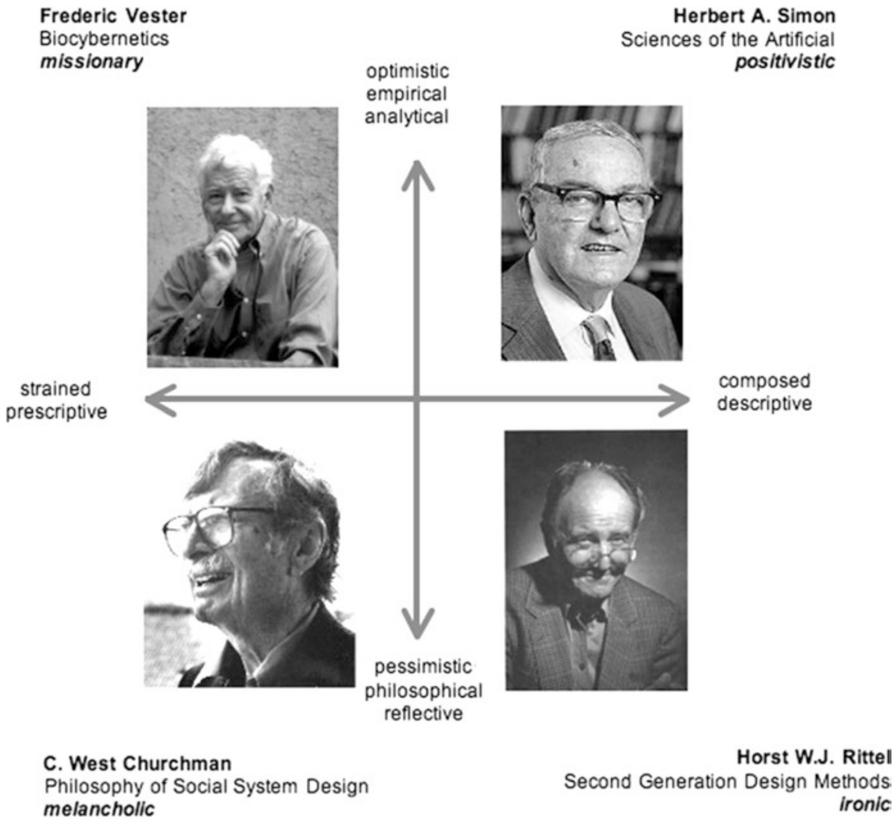


Fig. 1 Moods and attitudes of approaching systemic design (Jonas, 2014)

The Basic Problems of Complexity and Uncertainty/Control and Prediction

Herbert Simon (1969) and Christopher Alexander (1964) consider design as an interface-building discipline, bridging knowledge gaps between inner and outer environments (the artefacts and their contexts). The interface denotes the borderline between what can be designed and what has to be considered as given conditions. German sociologist Dirk Baecker (2000) differentiates this view. In describing the inner/outer environment, he builds on Niklas Luhmann's (1984, 1996) social systems theory, in which humans/persons are conceived as combinations of two closed, but structurally coupled, autopoietic systems: bodies and consciousnesses (Maturana & Varela, 1987). The social domain is created by a third autopoietic system, which is communication. The autopoietic closure of these three system types means that they cannot control but only irritate/perturb each other; they operate according to the possibilities and restrictions of their own internal structure and organization. Thus Baecker (2000, p. 163) argues that design, as the "practice of not-knowing," is the agency, which deals with bridging knowledge gaps between these causally decoupled systems, which are each described by a more or less elaborate knowledge. If these knowledges are brought into a relation of difference, the knowledge disappears and makes room for the experiments of design. This hybrid constellation of incompatible entities establishes the "design system" or the "inquiring system," respectively.

This assumption implies two fundamental epistemological problems in design that we need to align: *the problem of control* and *the problem of prediction*. In futures studies terms, one might speak about irreducible systemic complexity and multiple evolutionary futures (Gausemeier et al., 1996).

The Problem of Control (Irreducible Complexity)

It is impossible to fully recognize design situations in their systemic complexity. Simon's notion of "bounded rationality" (Simon, 1991) leaves open whether this is a practical limitation or a theoretical condition. Mikulecky (no year) gives a definition of the related complexity:

> Complexity is the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its properties. It requires that we find distinctly different ways of interacting with systems. Distinctly different in the sense that when we make successful models, the formal systems needed to describe each distinct aspect are NOT derivable from each other.

This relates to what Alain Findeli (2010) calls the "scope" or field of design research, which aims at the habitability of the world:

> … it refers to the interface and interactions between individual or collective 'inhabitants' of the world (i.e. all of us human beings) and the world in which we live (i.e. our natural and artificial environments, which includes the biocosm, technocosm, sociocosm and semiocosm). (p. 292)

As a consequence, systems thinking/network thinking should be adopted as the "super method" with special attention to boundary judgements, levels of abstraction/aggregation, and perspectives of observation.

The Problem of Prediction (Multiple Evolutionary Futures)

Design processes are evolutionary, based on the past and experimenting with the new. In principle, design (and science) is creating variation in sociocultural evolution, which in total consists of a sequence of variation, selection, and re-stabilization. The conscious design process (in my terminology: Analysis – Projection – Synthesis) covers just the variation part of the overall evolutionary trial-and-error process (Michl, 2002). By means of research, design tries desperately to achieve more control of the selection and re-stabilization phases. Herbert Simon, despite often being labelled as the positivist, has realized this, at least in the context of social design. He clearly dismisses the claim to forecast future events and introduces the notions of normative scenarios and backcasting procedures (Simon, 1969, 1981, 1996): "The heart of the data problem for design is not forecasting but constructing alternative scenarios for the future and analysing their sensitivity to errors in the theory and data (p. 148)." In his explicitly evolutionary theory, he refuses the concept of fixed goals for planning, and argues that social planning is necessarily myopic, trying to generate a future that is a little better—or fitter—than the present. The new situation serves as a starting point for further goal setting and continued design activity (Simon, 1969, 1981, 1996):

> What we call 'final' goals are in fact criteria for choosing the initial conditions that we will leave to our successors. … One desideratum would be a world offering as many alternatives as possible to future decision makers, avoiding irreversible commitments that they cannot undo. (p. 163)

Maybe this is Simon's greatest contribution to the further discussion: recognizing design thinking as a powerful discursive tool of inquiry to be used in processes of negotiating options and generating knowledge of possible and desirable future states. Not for fixing goals, but just to keep things in flux, to keep options open. Ethics remains subliminal, implicit in the process. Findeli (2010) makes the "stance" or epistemological bent of design research explicit:

> Indeed, design researchers … not only look at what is going on in the world (descriptive stance), they look for what is going wrong in the world (diagnostic stance) in order, hopefully, to improve the situation. … design researchers consider it [the world] as a project (of design). Their epistemological stance may thus be characterized as *projective.* (p. 293)

A further consequence: Evolutionary/projective thinking should be adopted as another "super method." Projection and exploratory or normative scenarios should be used instead of prognosis and prediction.

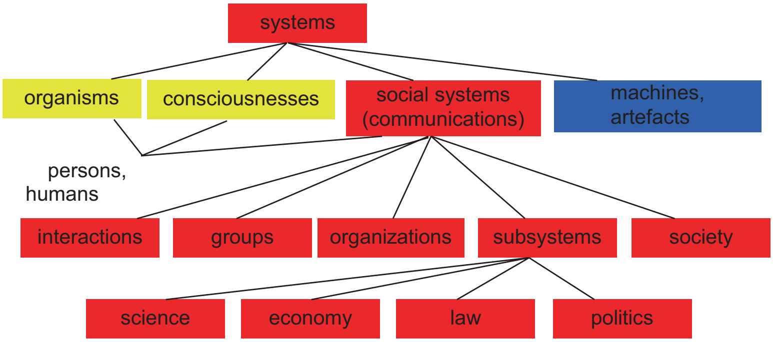


Fig. 2 Systems according to social systems theory (Luhmann, 1984, 1996)

Systemic Phases, Levels, and Structures

Defining and situating design activity in systemic terms, factually, socially, and temporally, is not at all trivial. The notion of knowledge or causality gaps and of the fundamental problems of prediction and control is based on the theory of social systems (Luhmann, 1984, 1996): Organisms (bodies), consciousnesses, and communications are conceptualized as closed, autopoietic systems. The second row of Fig. 2 refers to the design definition given in section *The Basic Problems of Complexity and Uncertainty/Control and Prediction*, above: Design means to bridge the knowledge gaps between organisms, consciousnesses, and communications by means of artefacts.

The theoretical model must be related to real-world conditions and developed into operable methods and terminologies. Numerous explanatory frameworks are available for this purpose. It is essential to be aware of the sociocultural development phase one is acting in (contextual conditions, "wickedness" of problems), the systemic level of the design process (individual, company, society), and the level of reality and the level of observation and explanation one is using in the process of inquiry (symptoms, behaviour patterns, underlying causes, and value structures).

Changing Design Contexts and Conditions

Contextual conditions are constantly changing. The schema of design contexts (Jonas, 1997a) with three temporal phases, as suggested in Fig. 3, manifests in various dimensions. Regarding, e.g. the relation of need between products and people:

1. We had—and still have—a situation of *linearity* (need), with products more or less successfully solving problems related to (basic) needs.

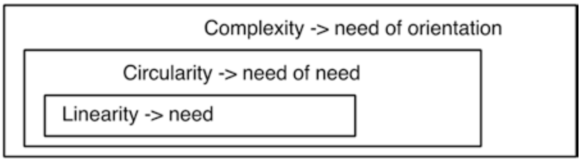


Fig. 3 Phases of changing design contexts (Jonas, 1997a)

2. We had—and still have—a situation of *circularity* (need of need), with products promising to solve problems; to give status, meaning, happiness, etc.; and, even more importantly, to serve as catalysts in the accelerating production-consumption cycle. Max-Neef (1991) describes this as the economically driven creation of new ways to satisfy a limited number of basic needs.
3. And we are facing a situation of *complexity* (need of orientation), with contexts and environments that make sense or do not. Products become more and more secondary in this situation; design outcomes are increasingly complex product-service systems.

Current futures studies confirm this diagnosis and emphasize that the aim of futures studies is not to predict but to provide orientation in complex and dynamic environments (Gerhold et al., 2015).

This early model seems to be similar to what Pourdehnad et al. (2011, p. 4) now call First, Second, and Third Generation Design. And there are striking parallels to Buchanan's "four orders of design" (Buchanan, 2001); to NextDesign's "Design 1.0, 2.0, 3.0, and 4.0" (Van Patter & Jones, 2013); and even to Krippendorff's "trajectories of artificiality" (Krippendorff, 2006). This leads to considerations regarding the levels of the design process.

Levels of the Design Process

Designers are required to act consciously on the different *levels of the design process*. This refers to the third row in Luhmann's scheme (see Fig. 2). In Jonas (1994) I propose a systemic framework for design, considered as an autopoietic subsystem—named *designing*—nested in the autopoietic supersystem society, the emergent levels being individuals, teams, companies (the traditional design discipline was placed here), subsystems (science, economy, and designing), and society. *Designing* is conceived as an interdisciplinary network of future-shaping disciplines, including design, situated on the level of subsystems like science or economy. The argument was to strengthen theory work in the two outer boxes of Fig. 4.

There are many other systemic hierarchies that emphasize different theoretical, methodological, and practical aspects. Cooper and Press (1995) identify four pragmatic levels: (1) design as an internal creative process, (2) design as an external productive process, (3) the total process of design within management, and (4) design as a planning process. Riedl (2000) provides a comprehensive learning theory of

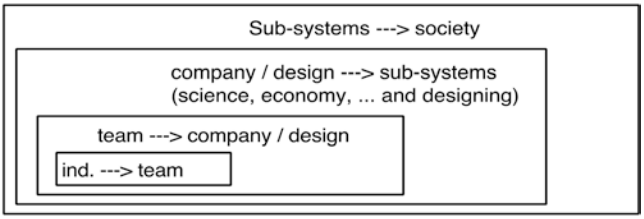


Fig. 4 Four emergent levels of the design process from individual to society (Jonas, 1994)

understanding and explanation, valid from the molecular to the cultural level. Kossoff, Tonkinwise, and Irwin (2015) introduce the "holarchy in the natural world," which builds on the sequence of levels between molecules – cells – organisms – communities – ecosystems – planet, and finally derive what they call "domains of everyday life," household – village or neighbourhood – city – region – planet, which is comparable to Alexander's (Alexander, Ishikawa, & Silverstein, 1977) hierarchy in his *Pattern Language*. Meadows (2008) describes 12 levels of systemic reality plus the possible strategies of intervention. Geels and Schot (2010) develop the "socio-technical systems multilevel perspective," consisting of niche (micro), regime (meso), and landscape (macro) levels of activity. WBGU (2011) is using a hierarchy from niche actors towards the designing state and finally global cooperation for explaining transformatory scaling processes in a bottom-up manner.

Levels of Reality (Observation and Explanation)

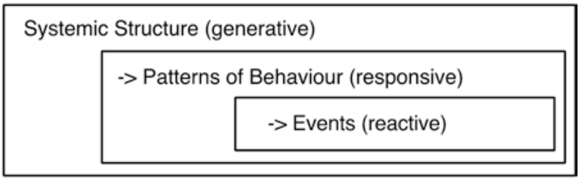
Systems thinking requires designers to act on several *levels of reality* and communicate this in systemic language. It is about carefully reflecting one's own perspectives of observation and explanation. Senge (1990) differentiates events, patterns of behaviour, and systemic structures. Systemic structure is concerned with the interrelationships that influence behaviour over time. These are not relations between people, but among key variables (descriptors), such as population, natural resources, etc. "Structure produces behaviour" is Senge's "first principle of systems thinking," and changing underlying structures can produce new behaviour patterns. Structural explanations are inherently *generative* (Fig. 5).

Causal layered analysis (Inayatullah, 1998) distinguishes four levels of inquiry, the first three being comparable to Senge's:

1. The *litany* includes quantitative trends, often exaggerated and used for political purposes. Inayatullah calls this "the conventional level of futures research which can readily create a politics of fear."
2. Social *causes*, including economic, cultural, political, and historical factors.
3. *Structure* and the *discourse* that legitimizes and supports the structure.
4. *Metaphor* and *myth.*

Both Senge and Inayatullah mention our involvement in systemic structures. The following will reflect the delicate epistemological implications in more detail.

Fig. 5 Levels of reality (Senge, 1990)



The Concept of the Inquiring/Design System

The above reflections about irreducible complexity and future uncertainty, combined with the constructivist assumption of observer involvement, suggest to elaborate on observation modes of first and second order. We don't have clear and distinct Cartesian observer situations anymore; the classical separation of nature and society is becoming obsolete. West Churchman's (1970) harsh and slightly mocking critique of Simon's *The Sciences of the Artificial* (Simon, 1969), entitled *The Artificiality of Science*, brings this to the point:

> Simon begins his book by trying to distinguish the 'natural' from the 'artificial'. Natural science, he says, is 'knowledge about natural objects' (p4). What he does not go on to say, perhaps because it would ruin his distinction, is that natural science is artificial; it is, in fact, one of the greatest and most mysterious artefacts man has ever created.

Churchman and Simon are usually considered as antagonists regarding systemic design; I see them as complementary. Werner Ulrich (1979) presents a fictional debate for clarifying the metaphysical and normative content of both positions. Simon relies on objectivity, insists on the semantic precision of concepts, and adheres to the principle of the excluded third. Mathematical modelling and simulation are his preferred tools. Churchman relies on subjectivity, reflecting the sources of knowledge and delusion, and acknowledges the transdisciplinary principle of the included third. Ideas, analogies, personal experience, and affectivity are important issues; moral consciousness, permanent self-reflection, and debate are essential for the unfolding of divergent problem views. Churchman's (1968) central question is: "How can we design improvement without understanding the whole system?" (p. 3), and Ulrich (1994, p. 2) goes further and asks "But what constitutes an improvement?"

The challenge arising from these difficulties is to develop more sustainable theoretical foundations and conceptual tools of critical reflection and debate that help to uncover the inevitable incomprehensiveness and selectivity of our problem definitions and designs. The basic *paradox* of every design situation as, for example, stated by Rittel (1972)—the more we know, the less we can rely on rational decisions—has to be resolved by multi-perspective, time-consuming dialogic procedures. We have an iterative Darwinian learning process rather than a rational Cartesian choice. Churchman's great contribution is the concept of the *inquiring system* (Churchman, 1971). These knowledge-generating entities are "inhabited by people," acting in different roles as clients, decision makers, and planners/designers. Knowledge production follows different philosophical and epistemological stances, and we have to be aware of our respective engagement in the process:

The Leibnizian Inquirer is a closed rationalistic, reductionist Cartesian system, a fact net of deductive reasoning based on axiomatic foundations. Theorem-proving software (Simon's *General Problem Solver*) or expert systems are operationalizations of the Leibnizian Inquirer.

The Lockean Inquirer is an open empiricist system of inductive reasoning based on sense data. Consensus and the validation of consensus is achieved in a social process, with all its deficiencies.

The Kantian Inquirer integrates the former two by presupposing some transcendental formal structure regarding time, space, and causality. Models and representations are applied to the observed data; multiple perspectives are possible. "Goodness of fit" is the measure of validity.

The Hegelian Inquirer acknowledges that there are matters of fact that may be observed and verified by others and matters of value (or of concern) that cannot. Objectivity may only be achieved by including the values of those who will be affected by the inquiry. The infinite dialectic sequence of thesis–antithesis–synthesis can be interpreted as a kind of second-order observation or learning process.

The Singerian Inquirer embraces the four preceding ones. The pragmatic, goal-seeking, teleological process with an ethical base generates common knowledge for the resolution of social problems. The Singerian Inquirer aims at improving the degree of consensus about values; it seeks solutions that are ethical and even beautiful. There is no authority, no single element controlling, but control is pervasive and inherent, in a permanent flux between agreement and inconsistency.

Courtney, Chae, and Hall (2000) summarize this as follows:

> The Leibnizian approach provides rationality and logic, the Lockean brings in social intercourse, the Kantian multiple perspectives, the Hegelian, the dialectic and dialogue, and the Singerian, sweeping in them all and also adding a search for common knowledge. (p. 141)

Facts and values are inseparable in design. Figure 6 relates constellations of observer positions to the meanwhile widely accepted notions of research *For*, *About* and *Through* design. The red ellipsis represents the design/inquiring system, comprising the design agents and the design activity (subject and object of designing are inseparable). The yellow ellipsis denotes the relevant wider context. The dot marks the observer position; the arrow indicates the observer perspectives/intentional stances. A fourth category is emerging: Research *As* design (Glanville, 1997; Joost et al., 2016).

Facts and Values: Epistemic Democracy and RTD

Design research operates in a second-order cybernetic mode, reflecting its own involvement. De Zeeuw (2010) argues that formats such as action research or the soft-systems approach are still contested, because they permit contributions in the form of observations as well as judgements. Lykins (2009) suggests that "a better

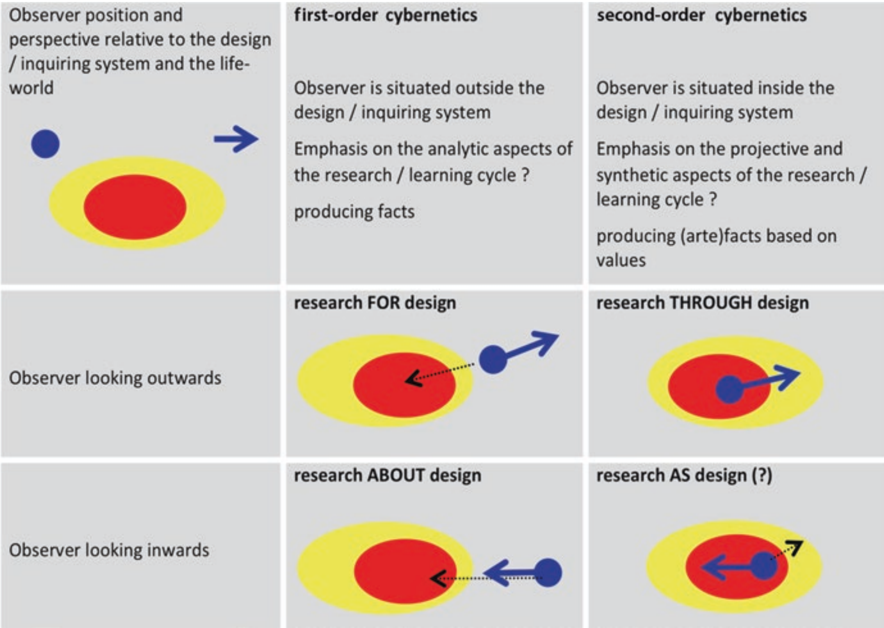


Fig. 6 The concepts of research For, About, Through (and As) design, related to observer positions and perspectives

understanding of the relationship between facts and values can lead to a more direct line between social science and social progress."

Max Weber (1864–1920) is the proponent of value neutrality. He conceives sociology as a science, which is aiming to understand and causally explain social action in its conditions and effects. Although Weber concedes that social inquiry arises from concrete needs and values, he argues that sociology cannot inform us as to what should be. Value claims can be justified only by appeal to some non-rational, arbitrary point, such as tradition or desire. Moral decisions are not reducible to empirical hypotheses.

Émile Durkheim (1858–1917) conceives social facts and structures as matters of fact, which are to be discovered by the sociologist. They determine human acting. Methods and epistemic standards of natural science must be maintained if there is to be social science. Furthermore, science can provide a way of assessing value claims objectively. The definition of "good" can be discovered through an analysis of actual conditions. Social "sickness" is indicated by deviations from the average state. This position has been criticized as "naturalistic fallacy."

John Dewey (1859–1952) argues that facts (means) and values (ends) are interdependent and differ only in degree. An isolated factual statement offers little direction for future conduct. A value statement is contextual and temporal and expresses significance since it involves a judgement about the consequences of an action. This is the only difference between facts and values. One means taking things as they are,

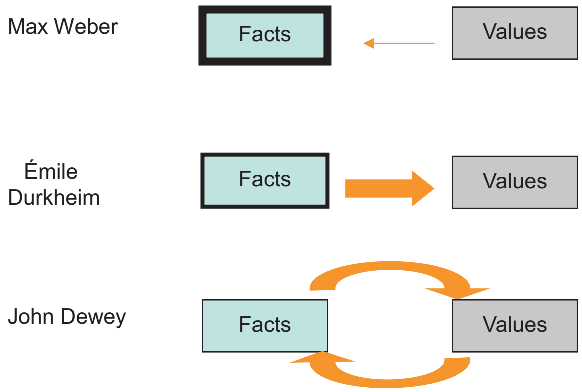


Fig. 7 The relation of facts and values in sociological theory (Adapted from Lykins, 2009)

the other taking things in their relations to antecedents and consequences. The difference between scientific study of natural and social questions is due to the degree of complexity of the relations under investigation (Fig. 7).

Dewey argues that the criteria for evaluating ends come *from within the situation itself*. This means that epistemic heterogeneity has to be taken as an essential condition for relevant inquiry. Anderson (2006) argues for the epistemic benefits of democracy and realizes the problem of forming a public that can understand and respond to its own problems. Latour (2003, 2004) proposes that scientific and political debate should be taking place in a common space. He discusses "collective socio-scientific experiments," which are no longer conducted in the laboratory but involve wider communities and in some cases the population of the world as a whole. De Zeeuw (2010) suggests a "hybrid" form of research for social intervention that makes use of both observations and judgement without ignoring the distinctions between them. The new form of research should (De Zeeuw, 2010) "include the dilemma as part of its knowledge production" (p. 8). This is apparently a problem of contextualisations, of boundaries or interfaces, and of whole systems ethics in Churchman's sense (Churchman, 1968).

Research that excludes judgemental contributions can be referred to as *Cartesian* (or Leibnizian). It consists of declarative statements that connect observations and support prediction in terms of their connections. Research that includes judgemental contributions is processual and evolutionary and has a *Darwinian* (or Singerian) flavour; it aims at the breeding of more competent collectives. Autopoietic closure may create collectives as observing and acting and knowledge-producing systems. This means a shift from satisfying observed needs towards enabling collectives to become social actors who define preferred states. Christakis (1996) suggests a "people science" that performs a "'shift' from an individual-centred conception of knowledge and understanding to one that is socially-based." John Chris Jones (1999) introduces the Internet-based notion of "creative democracy": "a vision of the future in which the controlling roles and functions of modern life could be shared with everyone" (p. 407).

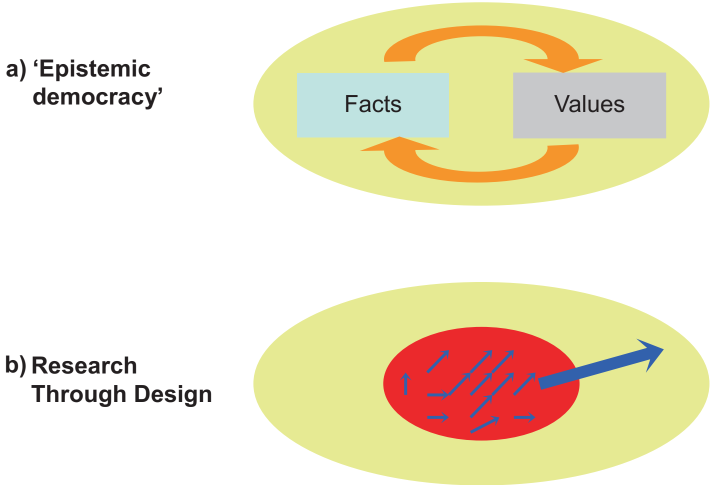


Fig. 8a, b Epistemic democracy establishes the *design/inquiring system* as the basis of RTD

The concept of RTD (Jonas, 2007, Figure 6) may be the epistemic model for systemic design processes, a specific mode of designerly inquiry and action that allows and supports "epistemic democracy" (Fig. 8a, b): The ongoing reflection of facts and values within a *wider context* of relevance (bigger ellipsis) generates a *design/inquiring system* of the Churchman type (smaller ellipsis), which creates the *driving force* for the transformation (arrows). This simple-sounding assertion opens the vast and complex field of *social choice theory*, which is concerned with the nontrivial question of how individual decisions based on a variety of perspectives and priorities can be bundled to collective judgements with respect to social welfare (Arrow, 1963; Sen, 2008, 2009). In design terms, this question marks the difference between human-centred design and social transformation design, a largely unresolved issue (Jonas et al., 2015).

These considerations imply a transformation from *professional problem-solving* expertise (First Generation Design) to *participative projects* (Second Generation Design), directed by designers, and finally towards *collaborative/collective action* (Third Generation Design, Pourdehnad et al., 2011, p. 4), possibly—but not necessarily—facilitated by designers. The central difference with respect to Cartesian research lies in the inclusion of systemic complexity and evolutionary uncertainty in research situations, in the extended concept of the knowledge-generating entities, and in the inclusion of various knowledge types, including value-based judgement. Furthermore, synthetic ways of thinking and acting are considered as relevant research activities. All this results in higher complexity of the research situation and implies an increased demand for reflection, transparency, and carefulness in the process.

The Relation to Design Methodology

The theoretical considerations and clarifications (sections *Systemic Phases, Levels, and Structures*, *The Concept of the Inquiring/Design System*, and *Facts and Values: Epistemic Democracy and RTD*) have to be transferred into operable process models useful in systemic design contexts. The generic model of research through design, as described in section *The Concept of the Inquiring/Design System*, provides a basis for further operationalization.

Design Process Models, RTD as a Model of Systems Design Research

Design and design research can be considered as cybernetic, evolutionary processes of experiential learning (Kolb, 1984). There are various four-step models, such as Kumar's (2013), which directly relates to Kolb, as well as models with five or more steps. Three-step models reveal the underlying modes of inductive, abductive, and deductive inference most clearly, *abduction* being the central phase of creating the new. Table 1 provides a representative overview. The analogies of the RTD framework of Analysis – Projection – Synthesis (Jonas, 2007) to other terminologies such as *transdisciplinarity studies* (Nicolescu, 2002) are obvious.

As explained in section *The Basic Problems of Complexity and Uncertainty/Control and Prediction*, we face the basic problems of *control*, due to systemic complexity, and of *prediction*, due to future uncertainty. They are associated with the Analysis and the Projection phases of the process, which are the social locations of systems thinking and design, or (Findeli, 2010) of dealing with the broad *scope* and the projective *stance* of the process. Systems thinking and scenario building have been identified as "meta-methods" (Table 2).

The Relevant Systems in RTD: The Problem of Control

Simon (1969) asserts that:

> … an artifact can be thought of as a meeting point—an 'interface' in today's terms—between an 'inner' environment, the substance and organization of the artifact itself, and an 'outer' environment, the surroundings in which it operates. If the inner environment is appropriate to the outer environment, or vice versa, the artifact will serve its intended purpose.

This implies that we have to determine and analyse the "outer environment," the external conditions, or *the wider context* (the bigger ellipsis in Figs. 8a, b and 9), as well as the "inner environment," the system to be designed. In systemic design, the

Table 1 Three-step models in design research suggest a generic model of the designerly research process

Authors	Phases/components/domains of knowing in design (research)		
	Induction	Abduction	Deduction
Jonas	Analysis	Projection	Synthesis
Research through design			
Simon (1969), Weick (1969)	Intelligence	Design	Choice
Jones (1970)	Divergence	Transformation	Convergence
Maser (1972)	Analyse what *is*	Project what *should be*	Create a plan/change reality
Transklassische Wissenschaft			
Archer (1981)	Science	Design	Arts
Gausemeier et al. (1996)	Scenario field analysis	Scenario prognosis	Scenario building
Futures studies			
Nicolescu (2002)	System knowledge	Target knowledge	Transformation knowledge
Transdisciplinarity studies			
Nelson and Stolterman (2003)	The true	The ideal	The real
Fallman (2008)	Design studies	Design exploration	Design practice
Brown (2009)	Inspiration	Ideation	Implementation
Schneidewind and Singer-Brodowski (2014)	Problem analysis	Vision development	Experiments/diffusion and learning
Transformative Wissenschaft			

Table 2 The generic RTD process in relation to transdisciplinarity studies and to system and scenario approaches

	The scope	The stance	
Jonas (2007)	Analysis	Projection	Synthesis
Research through design			
Nicolescu (2002)	System knowledge	Target knowledge	Transformation knowledge
Transdisciplinarity studies			
"Meta-methods" for the phases	System analysis/ modelling/sensitivity modelling	Scenario building/ exploring options	"Normal design"

artefact can be considered as both designing (the actors involved) and designed (the resulting form or interface); following Churchman, we call it *the design/inquiring system* (the smaller ellipsis in Figs. 8a, b and 9). Furthermore, this is denoted by Simon's "intended purpose"; we have to identify the *driving force* (the arrows in Figs. 8a, b and 9) or the value-based vision that drives and guides the design activity. Implications are as follows:

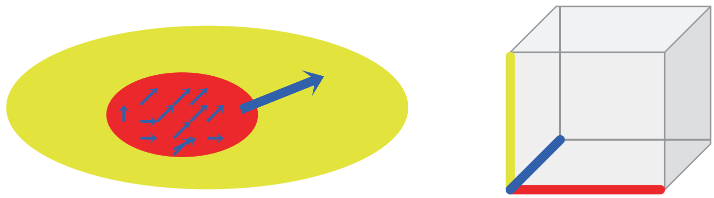


Fig. 9 The wider context, the design/inquiring system (established by the involved actors), and the resulting driving force (left). The Cube of Future Uncertainty (right) is a generic scenario framework corresponding to these three systemic dimensions

- For the wider context:
  - Clarify the relevant "facts" of the situation and its systemic relations (theoretical and empirical).
- For the design/inquiring system:
  - Clarify the system as regards to its constituents/stakeholders, its "nature" (Churchman's types, section *The Concept of the Inquiring/Design System*), its degree of autonomy, the designer's position (inside/outside), the designer's role, explicit and implicit agendas, schools of thought, values and judgements, etc.
  - Clarify the designer's professional position (regarding the client, the decision maker, the power constellation of designer-client-decision maker, etc.) (Brown, 2010).
  - Clarify and reflect on the designer's personal position (morals, values, biases, likes and dislikes, hidden agendas, etc.)
- For the driving force:
  - Clarify the drivers of the design activity (fears, hopes, wishes, etc.).
  - Clarify the motivations of the design activity (economic, emancipatory, scientific, etc.).
  - Clarify "the preferred situation" (the design goal).

Relating RTD to a Generic Scenario Model: The Problem of Prediction

The projective part of RTD, which deals with the problem of prediction and future uncertainty, requires further methodical support. *Scenario approaches* seem to be promising. Most of them operate with a limited number of key variables of high impact and high uncertainty. However, comprehensive scenario techniques require enormous effort and mathematical support, such as cross-impact analysis, cross-consistency analysis, and cluster analysis (Gausemeier et al., 1996; see Section 8). Schwartz's approach (1991) provides a simplified method with two or three key variables and two alternative extreme projections for each key variable (Fig. 9).

The Cube of Future Uncertainty can be considered as a generalized and simplified designerly model for scenario building. It uses three key variables, which correspond to the three above-mentioned systemic dimensions of RTD: The first key variable is taken from the *wider context*, the second is taken from the *design/inquiring system*, and the third reflects the *driving force*. Thus, by combining pairs of alternative projections of each variable, the framework establishes the logic for eight different scenarios (*otto stagioni*). Often the driving force is taken for granted, which results in four different scenarios (*quattro stagioni*).

The following section briefly introduces designerly tools for dealing with the Analysis and the Projection phase or the *scope* and the *stance* of design research.

Methodologies and Methods for Analysis and Projection

This section suggests designerly tools for systems design thinking: "meta-methods" for system modelling, system analysis, and scenario building. We briefly introduce the approaches of Vester, Schwartz, and Gausemeier and will relate them to each other. Gausemeier is the most comprehensive approach, integrating the others as simplified partial methods.

Sensitivity Modelling (Vester)

Sensitivity modelling (Malik Management Zentrum St. Gallen, n.d.) has its roots in biocybernetics and is based on the assumption that the specific instruments of isolated expert cultures are no longer appropriate for problem-solving in a complex world. The approach has been developed since the 1980s, primarily in the field of urban and regional planning, strategic management, mediation, etc. It provides a user-friendly communicative tool for modelling and analysing complex systems in a widely intuitive manner, suitable for designers and heterogeneous groups of stakeholders. Starting with the system description, there are multiple paths to proceed in order to refine the system model (Fig. 10).

The system description addresses the seven so-called spheres of life to collect a set of variables that describe the system: (1) Who is there (people)? (2) What are they doing (economy)? (3) Where does it happen (realm of space)? (4) How do they feel (human ecology)? (5) How does this affect the environment (energy and waste)? (6) What are the ways of connecting (communication infrastructure)? (7) What are the rules (laws and culture)?

The systemic relevance of the model is guaranteed by means of the so-called criteria matrix: Every variable can be checked with respect to its systemic characteristics; the set of variables should cover all characteristics of living systems. The quality of the system model does not depend on the quantity of detailed in-depth data but on the completeness and relational coherence of the description. Cross-

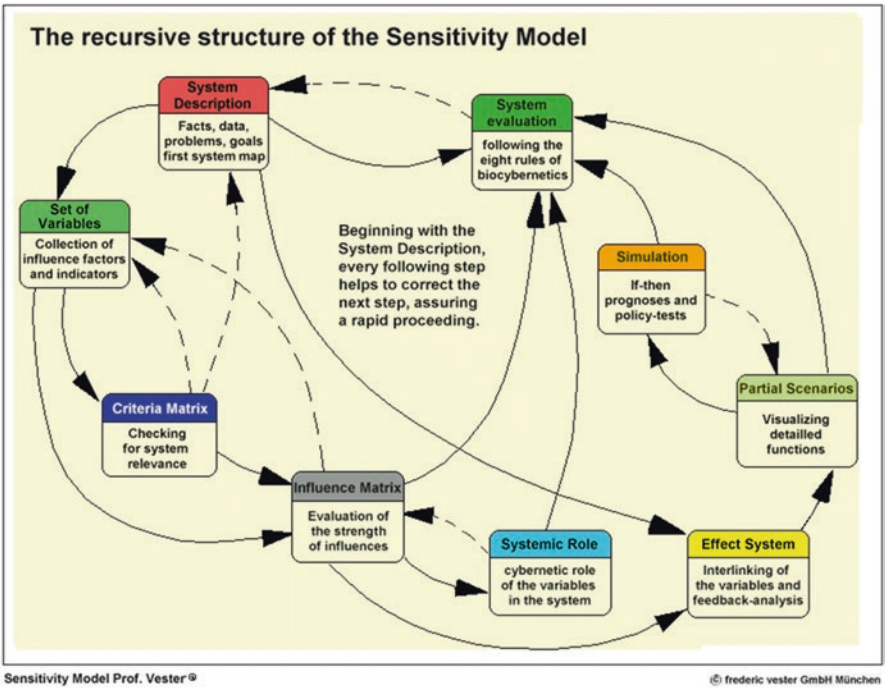


Fig. 10 The general recursive structure of sensitivity modelling. (From Ecopolicy software, original © F. Vester, licensed by Malik Management)

impact analysis allows investigation of the relations and the systemic roles of the variables. This may be a lever (active), a risk factor or an uncertainty (critical), a measuring sensor (reactive), an inert element (buffering), or any position in between. The definition of functional relations between variables allows for dynamic "what-if" simulations that give strategic clues regarding the sensitivity of the situation at hand. Sensitivity modelling covers Analysis and a smaller part of Projection. The tool explicitly restrains from predicting futures and suggests to use its analytical capabilities to understand the internal dynamics of the systems (Malik, no year). The method thus efficiently avoids slipping back into linear thinking. Its interactive and dialogic character makes it suitable for bundling a variety of perspectives and priorities into consensual collective judgements, as described above.

Intuitive Scenarios (Schwartz)

Schwartz (1991) provides a designerly method (*quattro stagioni/otto stagioni*; see section *Relating RTD to a Generic Scenario Model: The Problem of Prediction*) for exploratively dealing with future uncertainty (rough Analysis plus simple

Table 3 Scenario building guideline (Schwartz, 1991)

Step	Comment
1. Identify focal issue or decision	"The best way is to begin with important decisions that have to be made and the mindset of the management making them: …"
2. Key forces in the local environment	
3. Driving forces	"… listing driving forces in the macro-environment that influence the key factors identified earlier."
4. Rank by importance and uncertainty	"… The point is to identify the two or three factors or trends that are most important and most uncertain. … The results of this ranking exercise are, in effect, the axes along which the eventual scenarios will differ."
5. Selecting scenario logics	"… It is more like playing with a set of issues until you have reshaped and regrouped them in such a way that a logic emerges and a story can be told. …"
6. Fleshing out the scenarios	"… Each key factor and trend should be given some attention in each scenario. …"
7. Implications	"… time to the focal issue or decision identified in step one to rehearse the future. How does the decision look in each scenario? …"
8. Selection of leading indicators and signposts	"… If those indicators are selected carefully and imaginatively, the company will gain a jump on its competition in knowing what the future holds for a given industry and how that future is likely to affect strategies and decisions in the industry. …"

Projection). He introduces the method in a narrative way with many examples from the corporate context. The combination of Vester's analytical method and Schwartz's projective and explorative steps creates an efficient instrument for systems thinking and scenario-based design (see Table 3).

Model-Based Scenarios (Gausemeier et al.)

Gausemeier et al. (1996) conceive scenario management as the integration of systemic and future-open strategic thinking and acting. They provide the complete scenario process of Analysis, Projection, and Synthesis in full detail, mainly for application in the corporate context. The phases are called scenario field analysis, scenario prognosis, and scenario building, as introduced in Table 1 and shown in Fig. 11.

A special feature is the *morphological analysis* tool in the projective phase, which is necessary for developing consistent scenario/projection bundles from a number of key variables greater than 3.

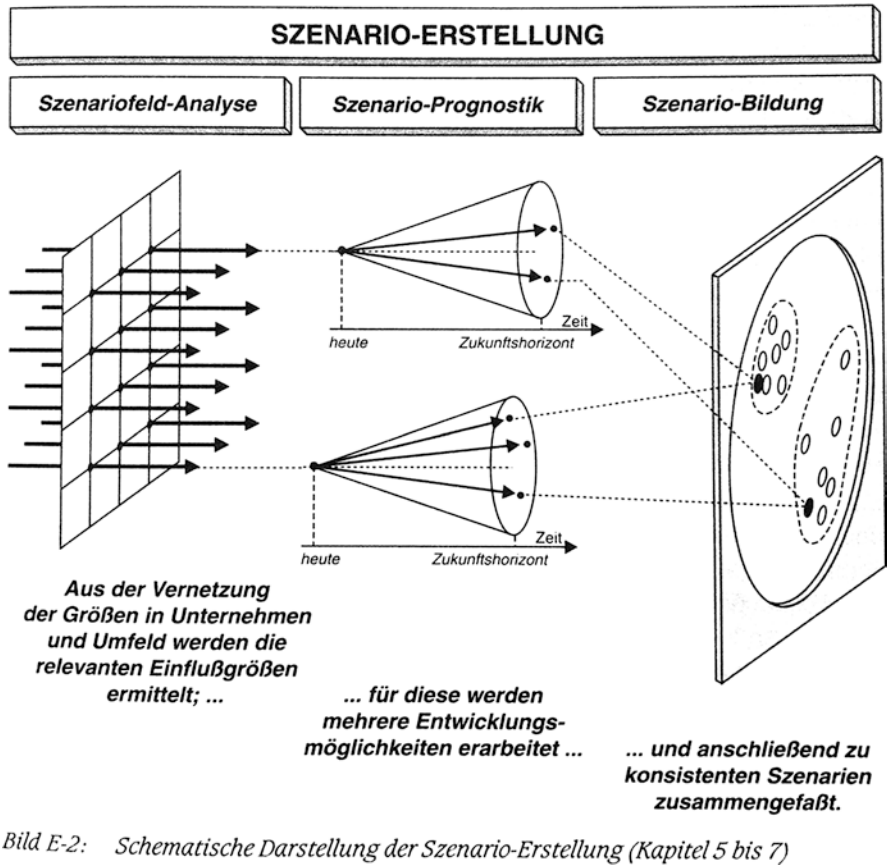


Fig. 11 Process of scenario building, following the generic sequence of Analysis, Projection, and Synthesis (Gausemeier et al., 1996)

Synthesis

For systemic design purposes, it makes sense to combine the three approaches. Analysis is best covered by Vester. For a comprehensive process, one should switch to Gausemeier after the Analysis phase. In order to avoid too laborious cross-consistency considerations and cluster analysis calculations, it is suggested to switch to Schwartz for the Projection phase. Strategic considerations (Synthesis) are covered by all three approaches, which productively complement each other (Table 4).

Before the background of the previous considerations, it is sensible and justified to conceive RTD (research through design) with its generic three-phase model of Analysis, Projection, and Synthesis, and futures studies and scenario planning in particular as largely equivalent, morphologically and epistemologically (see Table 1).

Table 4 Methodical integration of systems thinking and design based on Vester (1988), Schwartz (1991), and Gausemeier et al. (1996)

	Analysis	Projection	Synthesis
Vester	- Collection of variables - System modelling - Check system consistency by means of criteria matrix - Cross-impact analysis → Role of variables (active, reactive, critical, etc.) → Key variables	- Refinement of system model, establishing functional relations between variables - Dynamic simulations of the type "What happens if?"	
Schwartz	- Collection of variables (intuitively, expert assessment), much simpler than Vester - Assess variables according to impact and uncertainty → Key variables	→ *Quattro/otto stagioni* scenario frameworks with two or three critical uncertainties - Fleshing out the scenarios	→ Strategic considerations and decisions
Gausemeier	Comparable to Vester, but without criteria matrix → Key variables	- Determine possible future projections of key variables - Cross-consistency analysis of key variables - Morphological analysis/ cluster analysis → Projection bundles as raw scenarios - Fleshing out the scenarios	

The arrows denote shortcuts/branches between the different approaches

Conclusion

Systems Design Thinking As the Model of Transdisciplinary/ Transformative Science

We are completing the narrative cycle and come back to the German perspective and synthesis. In the early 1970s, Maser (1972) raised the question whether a theory of design is a theory according to classical science. His answer: Only partly, since although formal sciences, real sciences, and human sciences are applied in design, they do not comprise the total of a theory of design. The missing theory elements can be found in the so-called *trans-classical* understanding of the planning sciences. The starting point is always a concrete problem, whose solution requires contributions from the expert knowledge of various classical disciplines. The *project* is the location where the action is focused.

Science, conceived as a "service to mankind," leads to the demand for project selection by political and social priority, which resembles Krauch's (1972) position regarding the necessary public control of scientific research; this in turn, requires something like Dewey's "epistemic democracy."

Maser anticipated many of the fashionable new currents of rethinking science. He had been forgotten for almost 25 years, probably because he was arguing from a design perspective. The later concept of *mode-2 science* (Nowotny et al., 2001) provides a strong support of Maser's early claim. Nowotny (2006) calls *transdisciplinarity* a central feature of *mode-2 science*. While *mode-1* knowledge production is academic, investigator-initiated, and disciplinary-based, *mode-2* is problem-focused, context-driven, and interdisciplinary.

As shown in Table 1, there is a striking structural resemblance of RTD and *transdisciplinarity studies* (Nicolescu, 2002, 2008), which claim to integrate system knowledge, target knowledge, and transformation knowledge. In the RTD scheme, the first type of knowledge addresses the causes of present problems and their future development (system knowledge/Analysis). The second type concerns the values and norms that define the goals of problem-solving processes (target knowledge/Projection). The third type relates to the potential transformations and improvements of a problematic situation (transformation knowledge/Synthesis).

Nicolescu (2002, 2008) suggests three *axioms of transdisciplinarity*, which explicitly address the knowledge gaps between the different levels of reality and the perceiving subject:

1. The "ontological axiom": In nature and society, as well as in our perception of and knowledge about them, there are *different levels of reality* for the subject, which correspond to different levels of the object.
2. The "logical axiom": The transition from one level of reality to another is vouchsafed by the *logic of the included third*.
3. The "epistemological axiom": The structure of the totality of all levels of reality is *complex*; each level is determined by the simultaneous existence of all other levels.

Open transdisciplinarity (Brown, 2010) goes further and states the equal relevance of various heterogeneous knowledge cultures in a collective learning/designing process. "Specialized" (scientific) knowledge is but one of five relevant types comprising "individual knowledge," "local community knowledge," "specialized knowledge," "organizational knowledge," and "holistic knowledge." The concept explicitly contributes to the interface-building between epistemologically different "worlds" or to the bridging of "knowledge gaps."

Transformative science, as recently propagated in Germany (Schneidewind & Singer-Brodowski, 2014), adds a third mode of knowing to Nowotny's model (Table 5).

The further development of this proactive position, which has been developed so far, implies that it makes sense to conceive RTD (research through design) as the integrative medium of design and scientific research. Design has the chance to become a model for a new concept of science, i.e. the operational model of transdisciplinarity studies and transformative science (Table 6).

Table 5 Differentiation of mode-1 and mode-2 science and development towards mode-3 science

Mode 1	Mode 2	Mode 3
Weakly contextualized knowledge	Strongly contextualized knowledge	Strongly contextualized system, target, and transformation knowledge
Science largely without involving social perspectives	Society as central constituent of knowledge production	(Civil) Society as an actor in knowledge production and institutional organization of science
Disciplinary or in parts interdisciplinary	Transdisciplinary	Transformative
Homogeneous knowledge base, primarily from scientific institutions	Heterogeneous knowledge base from diverse institutions	Heterodox knowledge base from real laboratories and concrete transformation processes
Hierarchical organization structures of knowledge production	Anti-hierarchical organization structures	Cooperative organization structures of knowledge production
Disciplinary system of quality control	Diversified systems of quality control	Quality systems develop in the interplay of science and society

Adapted from Schneidewind and Singer-Brodowski (2014), p. 123 (translation W.J.)

Table 6 Research through design (Analysis – Projection – Synthesis) as the epistemological and methodological framework for design and scientific research

	Analysis/ induction/the true	Projection/ abduction/the ideal	Synthesis/deduction/ the real
Design practice, normal design			… just addresses a given brief
Scientific research, mode-1 science	… does not aim at change		
Mode-2 science, transdisciplinarity, RTD	System knowledge	Target knowledge	Transformation knowledge

Various perspectives and connections are finally showing up. John Dewey argues (1916) that only through the democratization of the means of social criticism can the tension between expert and lay authority be resolved. In short, the lay–expert question is best posed as an educational and social problem of enabling a citizenry to be able to conduct social inquiry. Democratic education shapes a community of heterogeneous *knowledges* that integrates facts and values in their inquiry and thus contributes to social progress (Brown, 2010). Practical answers to this problem of *epistemic democracy* are still highly controversial, as mentioned in section *Facts and Values: Epistemic Democracy and RTD*.

There is the relation to De Zeeuw's (1996 and 2010) *third-phase science*. De Zeeuw (2010) distinguished first-phase science, the Cartesian paradigm, dealing with non-constructed objects; second-phase science, dealing with constructed objects; and third-phase science, dealing with "self-constructing objects" (p. 19).

All this is supporting the hypothesis, supported by various evidence, that design and science are approaching each other (Chow et al., 2013). Latour's (1998) "transition from the culture of 'science' to the culture of 'research'" identifies the place where this convergence and permanent mediation work between nature and society are taking place: the laboratory (which is society). And the activity in the social laboratory is *design*. We are finally coming closer to Ranulph Glanville's great vision, which describes science and scientific research as a specific subcategory of design:

> Under these circumstances, the beautiful activity that is science will no longer be seen as mechanistic, except in retrospect. It will truly be understood honestly, as a great creative and social design activity, one of the true social arts. And its paradigm will be recognised as being design. (Glanville, 1980, p. 93)

I would like to supplement and clarify this with a personal conclusion: Ranulph Glanville once suggested that *cybernetics* might become "design's secret partner." Meanwhile I think that the fragile niche concept of design cybernetics with its exclusive and sometimes slightly esoteric touch needs a strong partner for its own survival. This partner—as illustrated in this chapter—might be the advancing and expanding discourse of systems design science. The subset of cybernetics is well taken care of there.

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Wicked Problems in Design and Ethics

Ben Sweeting

Abstract While the relationship between ethics and design is usually thought of in terms of the application of the former to the latter, it is not as if ethics is a settled body of theory that can authoritatively guide design practice. Depending on which theories or ideas we refer to, we receive different guidance as to what to do. Indeed, design may have as much to contribute to ethical theory as vice versa. This essay builds connections between design and ethics, looking to the similarities of structure between wicked problems in design and those dilemmas that are of central concern in normative ethical theory. Understanding design and ethics in mutual terms, ethical questions in design need not be understood in terms of external limitations or trade-offs between competing priorities. Moreover, the way designers cope with the ethical challenges presented by wicked problems may inform how we approach complex ethical challenges in other contexts, including some of those that arise within ethical discourse itself.

Introduction

The relationship between ethics and design is usually thought of in terms of applied ethics—as the application of normative ethical theories to design practice in order to navigate issues such as agency, professional ethics, and our relationships to technology and the environment. These considerations are vital given the significant impact that designers' decisions have on others, and there have been calls for designers to engage with ethical philosophy in order to grapple more fully with the ethical challenges they face (e.g. Schrijver, 2013; Spector, 2001). However, there are reasons to be cautious about seeing the relation between ethics and design primarily in terms of the application of the former to the latter. In addition to the general care that needs to be taken in understanding design in terms of other areas of theory (Glanville, 2004a, 2014a), such an approach implies that ethical

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considerations are separate to design questions. This is not borne out in practice, where designerly and ethical questions are closely intertwined (Lloyd, 2009; van de Poel, 2001) and virtues may be developed through design activity (Jonas, 2006). In any case, it is not as if ethics is a consistent body of theory that can straightforwardly act as an authority to guide design practice. Depending on which theories or ideas we refer to, we receive different and sometimes directly conflicting guidance as to what to, do. As Terry Eagleton (2003, p. 229) has noted, we might expect to agree on general principles and diverge on particulars, yet we have no common view on many everyday ethical questions. Even with those questions where we have widespread agreement over an action being ethically good or bad, there is little agreement on why this is the case. Whether we understand this state of disagreement as a conflict between objective goods (Berlin, 1998), an inevitable property of our subjectivity (Sartre, 1948), or resulting from the dissipation of any overall idea of the good life with which to make different goods commensurable (MacIntyre, 1985), the situation in which we find ourselves is that anything to which we refer to help clarify an ethical question is itself contestable.

There are significant parallels and overlaps between this and the concerns of the present volume in relating systems thinking and design. Both ethical philosophy and systems thinking offer support to designers in addressing the complex challenges they encounter. Indeed, some of the most pressing contemporary issues that designers face are both ethical and systemic in their complexity (consider, for instance, climate change or the complexities of sociotechnical systems). The history of the relation between design and systems thinking is also pertinent. During the 1960s, in what is usually referred to as the design methods movement, ideas from systems theory, cybernetics, the philosophy of science, and elsewhere were imported into design in an attempt to rationalize it. This lost sight of what was special about design in the first place and met with little success. Since that time, design's relationship to these fields has become more balanced, with the seemingly messier qualities of design having come to be seen as contributing to them as well as vice versa (Glanville, 1999, 2007b, 2014b, 2014c; Jonas, 2014; Jones, 2014a, 2014b; Sevaldson, 2017; Sweeting, 2016a). This has led to a more productive relationship, offering a pattern that could be followed in relating design and ethics: In addition to drawing on ethical theory to guide design practice, are there ways we might look to design activity with a view to informing ethics?

It is such a proposal that I put forward here, focusing on the systemic aspects of design and ethics in order to align them with each other. I draw on two main points of connection. The first is Horst Rittel and Melvin Webber's characterization of the complex situations that designers encounter as "wicked problems" (Rittel, 1972; Rittel & Webber, 1973, 1984), one of the most prominent and influential intersections of design and systems thinking, which also relates to ethical issues in content and structure. The second is the way that designers cope with this complexity, as it has been understood through the field of cybernetics. In particular I draw on the close analogy between cybernetics and design that has been articulated by Ranulph Glanville (2007b, 2009, 2014b), building on the Conversation Theory of his mentor Gordon Pask (1976), and the ethical reflections of cybernetics as developed by Glanville (2004b, 2005) and Heinz von Foerster (1991, 2003c).

Wicked Problems

One way of characterizing the complex situations that designers typically encounter is as what Rittel and Webber, writing originally in the context of planning, called "wicked problems" (Rittel, 1972; Rittel & Webber, 1973, 1984). Wicked problems are those that cannot be addressed using conventional methods of problem solving because of their uncertain boundaries, conflicting and incomplete requirements, and systemic complexities, such that the attempt to solve one problem may create others elsewhere. This contrasts with those well-defined problems that Rittel and Webber (1973, p. 160) label as "tame," which are typically associated with the hard sciences, rule-governed games such as chess, and highly regimented contexts such as the military. In the period of scientific and technological optimism that followed the Second World War, attempts had been made to apply competencies from these realms to more socially complex domains such as design. Rittel and Webber's analysis is notable for explaining the lack of success of such attempts, diagnosing those characteristics of such situations that preclude approaches that rely on being able to fully analyse the situation or define goals at the outset.

Rittel and Webber (1973) formulate this in ten[1] concise and interrelated points, each stressing the difference to the sorts of methods applicable to tame problems:

1. "There is no definitive formulation of a wicked problem" (Rittel & Webber, 1973, p. 161).

   Whereas tame problems can be exhaustively formulated in a way that contains all the information necessary to form a solution, for instance, as with the description of a chess puzzle, wicked problems are typically presented in an ambiguous and incomplete manner. Whichever way we initially address a wicked problem, it leads in turn to new questions and the need for further information. This means that a large part of addressing wicked problems is the formulation of the problem itself. Indeed, rather than moving from problem to solution, the "process of formulating the problem and of conceiving a solution (or re-solution) are identical, since every specification of the problem is a specification of the direction in which a treatment is considered" (Rittel & Webber, 1973, p. 161). Further questions emerge from the process of addressing the initial problem and cannot be anticipated ahead of time without prior "knowledge of all conceivable solutions" (Rittel & Webber, 1973, p. 161), which, if it were possible, would mean the problem was no longer wicked (c.f. feature 6).
2. "Wicked problems have no stopping rule" (Rittel & Webber, 1973, p. 162).

   With tame problems there is a definite end point where it is possible to know that an answer has been reached. With wicked problems the question of when and how to stop is much more arbitrary. Because the attempt to solve a wicked problem coincides with the attempt to understand it (feature 1), a process that has no obvious boundaries, our understanding and proposals are always provi-

[1] While in Rittel's (1972) *On the Planning Crisis* the equivalent list has 11 entries, Rittel and Webber's (1973) *Dilemmas in a General Theory of Planning* merges the first two of the list.

sional. We can stop at any point where we consider our proposal "good enough" (Rittel & Webber, 1973, p. 162), and, should we wish to, we could always continue to try to develop it further, or explore alternatives, were it not for criteria or limitations that are external to the problem itself, such as a lack of time or fees.

3. "Solutions to wicked problems are not true-or-false, but good-or-bad" (Rittel & Webber, 1973, p. 162).

   Whereas a tame problem will have a right answer (or set of right answers) according to established criteria, potential resolutions to wicked problems will only be better or worse, good enough or not good enough, viable or unviable.[2] These sorts of judgements may even vary with different stakeholders and criteria (Rittel, 1972, p. 392)—a solution may be good for one person but not for another, and so some solution may possibly be *both* better *and* worse simultaneously in different terms. Any proposed solution to a wicked problem is therefore not just provisional in the sense that one could keep working to improve it (feature 2) but also deeply contestable, especially given the uncertain boundaries (feature 1) and the resultant likelihood for new criteria to emerge and existing ones to change or lose relevance, bringing previous assumptions into dispute (c.f. feature 4). As Rittel and Webber (1973, p. 160) note, wicked problems "are never solved. At best they are only re-solved—over and over again."

4. "There is no immediate and no ultimate test of a solution to a wicked problem" (Rittel & Webber, 1973, p. 163).

   With a resolution to a tame problem, it is possible to identify points where its consequences are clear and evaluation can take place. Solutions to wicked problems, however, have consequences that unfold over long periods of time (consider, for instance, the way that buildings tend to outlive their initial uses, users, designers, and clients). One can only make a final judgement after all the consequences have played themselves out, yet, as there is no time limit to this, no such judgement can be made. Any evaluation of a resolution to a wicked problem is therefore as provisional as the resolution itself (feature 2), as further consequences may arise in the future that outweigh those that have already occurred.

5. "Every solution to a wicked problem is a 'one-shot operation'; because there is no opportunity to learn by trial-and-error, every attempt counts significantly" (Rittel & Webber, 1973, p. 163).

   Whereas with tame problems one can always start over again, one cannot, for instance, build a motorway to see if it is a good idea to do so. In addition to the resources that are consumed in the process and the significant effects on people's lives (c.f. feature 10), in enacting a solution, one changes the substance of the problem itself. It is not, therefore, possible to work by trial and error as even if it were possible to remove previous solutions, one cannot return to the

[2] Note that the basic criterion of viability will often still be tough to meet. Wicked problems may have no right answers, but they still have plenty of wrong ones.

original situation because the history of implementation and removal remains and what was learnt from the earlier attempt may not still be applicable.

6. "Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan" (Rittel & Webber, 1973, p. 164).

   Wicked problems cannot be stated as a finite list of options for consideration. Instead, "anything goes"[3] in terms of potential approaches, and "any new idea for a planning measure may become a serious candidate" (Rittel & Webber, 1973, p. 164). Resolving a wicked problem is therefore not just a matter of comparing various established possibilities with each other and settling on the best—or least worst—amongst them.

7. "Every wicked problem is essentially unique" (Rittel & Webber, 1973, p. 164).

   Although one can learn about the nature of wicked problems generally, each one is individual, and successful strategies cannot be directly applied from a past situation to a new one. There can therefore be no universally applicable method for solving wicked problems, although we can repeat strategies at a more general level.

8. "Every wicked problem can be considered to be a symptom of another problem" (Rittel & Webber, 1973, p. 165).

   The interdependency of wicked problems means it is not clear which problem it is best to work on. Approaching the situation on a more general level may make it harder to achieve change. Yet, addressing more specific issues risks treating the symptoms rather than the cause, while incremental improvements may also have unforeseen negative consequences elsewhere in the system and in the system overall, such as has become especially evident with human attempts to intervene in ecological systems and environmental crises (see, e.g. G. Bateson, 2000; M. C. Bateson, 2005).

9. "The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution" (Rittel & Webber, 1973, p. 166).

   Because of their incomplete and uncertain formulation (features 1 and 8), it is possible to explain wicked problems in many ways, and these explanations cannot be definitively resolved between because the situation is unique and there is no opportunity for full testing (features 5 and 7). Given that the formulation of the problem coincides with the search for a solution (feature 1), this contestable choice of explanation is instrumental in what resolution we propose and different characterizations of the problem may lead to conflicting prescriptions for action.

10. "The planner has no right to be wrong" (Rittel & Webber, 1973, p. 166).

    Unlike science, where progress is generated through the refutation of hypotheses and so error is an integral and acknowledged part of the process, the

[3] This phrase recalls that of Paul Feyerabend (1970, 1993) in his critique of scientific method. Rittel and Feyerabend were colleagues at UC Berkeley. On the parallels between their arguments, see Sweeting (2016a).

> effects of resolutions to wicked problems matter a great deal to the people they affect. This aspect leaves designers in a bind when considered with (feature 3)—there is no way to be right but no right to be wrong. Thus, the impossibility of being right does not support being unrigorous and irrelevant or acting only out of personal preference.

Given that "all essential planning [design] problems are wicked" (Rittel, 1972, p. 392) rather than tame, these ten features have profound consequences for the methods that designers can employ and for the status of the resolutions and evaluations that they put forward. There is insufficient clarity at the outset to use methods that rely on exhaustive analysis and information gathering or to define goals at which to aim, ruling out forms of rational linear problem solving or optimization that are applicable in more constrained contexts (feature 1). Methods such as trial and error (feature 5) and comparative analysis (feature 6) are inapplicable, one cannot rely on precedent (feature 7) or resort to personal preference (feature 10), and even incremental improvement has significant limitations (feature 8). Moreover, as it is not clear which problem is to be addressed (features 8 and 9), apparently conclusive options for resolution are themselves contestable, as they are dependent on how the situation is characterized.

Conversation and Design

Underlying each of the features that Rittel and Webber describe is the way that design is always concerned with creating the new. It follows that it is not possible to fully analyse the situation in advance or to definitively frame the problem at hand because new questions, and with them new criteria, emerge in the process as the situation is explored. Given that the purpose of design is to transform an existing situation into a new one in some way, it is, in effect, design activity itself that leads to the wickedness of the situations that designers encounter. This means that designers encounter wicked problems as a matter of course, and from their point of view, it can sometimes be difficult to see what the fuss is about. This is not to say that designers generate solutions to wicked problems—indeed the point of wicked problems is that they cannot be solved (features 2, 3, and 4). Rather, designers transform them, reformulating the situation to create different possibilities and relationships, and it is in coping with ill-defined situations such as these that designers can claim disciplinary expertise. That designers can approach such situations with confidence is due to the distinctively interactive way in which they work. This is often thought of in terms of a conversation that designers hold with themselves and others, such as in Schön's (1991, p. 76) characterization of design as a "reflective conversation with the situation" and the accounts of many others (e.g. Cross, 2007; Dorst, 2015; Dubberly & Pangaro, 2009, 2015a; Gedenryd, 1998; Glanville, 2006, 2007b, 2009; Goldschmidt, 1991; Jones, 2010; Khaidzir & Lawson, 2013; Lawson, 2004; Pangaro, 2008).

One way of exploring this further is via cybernetics, a field where conversational forms of interaction are of central concern. In particular, Glanville (2006, 2007b, 2009), whose work I take as a foundation for my own account here, has established a close analogy between (1) conversation, understood through the work of cybernetician Gordon Pask, his mentor, and (2) the core design activity of sketching, which Glanville takes as characteristic of what is distinctive about design more generally.[4] Both sketching and conversation are circular processes, with evaluations of previous actions influencing present ones. In sketching, this circularity is created by our shifting perspective between looking and drawing, paralleling the turning around between listening and speaking in a conversation. The etymology of conversation reflects this: To converse is "to turn oneself about," a phrase that historically has held social and ethical connotations in the sense of "keep company with" and one's "manner of conducting oneself in the world or in society" (Conversation, n.d.; Converse, n.d.).

As is familiar from our everyday experience, the direction of a conversation tends to evolve as it continues, heading in ways that cannot be predicted in advance. In Pask's (1976) Conversation Theory, this tendency towards the new follows from the way that meanings are not transferred between participants but, rather, participants construct their own understanding of the understanding of others, with the process taking the recursive form of "what I think of what you think I think, etc." (Glanville, 1993, p. 217). For instance, if, in a two-person conversation, I begin by presenting some idea, the other participant does not simply have this transferred to them but builds their own understanding of what it is that I mean. They then present what they have understood back to me, and, again, I construct my own understanding of their presentation. I can then compare this understanding (what I understand of what they understood) to what I originally meant to communicate. Even if we continue this process in order to align our respective understandings, they remain separately constructed. This conversational mechanism allows us to act as if we understand the same thing without the need for any message containing this understanding to be passed between us, allowing for the coordination of communal understanding while also maintaining and establishing difference between participants. The maintenance of this difference means that conversation is not just (and often not even[5]) a way to reach agreement about existing ideas. It is also a way to generate new ones: whether directly from our understanding of what is shared with us; through misunderstanding, where we see an idea in what someone says that was not intended; or where we learn what is implied by our own ideas through understanding how they are interpreted and understood by others.

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[4] On the relation between cybernetics and design, see also, e.g. Dubberly and Pangaro (2007, 2015a, 2015b), Fischer (2015), Fischer and Richards (2017), Furtado Cardoso Lopes (2008, 2009), Gage (2006, 2007), Glanville (2007a), Glanville and Sweeting (2011), Herr (2015), Jonas (2007, 2015), Krippendorff (2007), Krueger (2007), Pask (1969), Pratschke (2007), Ramsgard Thomsen (2007), and Sweeting (2015a, 2016a).

[5] While we can try to reach agreement, we will often abandon the attempt either through frustration or, alternatively, through the agreement to disagree (Pask, 1988, p. 85).

Similarly to the combination of speaking and listening in conversation, design combines the making of proposals with evaluating and understanding them. The circular process formed by these two aspects is more than one of iterative improvement or optimization against set criteria. Just as conversation can change course or develop new questions to explore rather than just leading to agreement, designers review and revise not just their proposals but also their understanding of the situation for which these proposals are intended. This can be seen in the core design activity of sketching, where designers simultaneously play the roles of speaker (drawing) and listener (looking), continuously switching between the two. By externalizing their thoughts through a medium, designers see more in what they have drawn than they originally intended or understood, generating new possibilities for proposals or identifying further aspects of the situation that need to be taken into account.

While there are many other aspects to what designers do, it is this conversational way of working, most evident in sketching but characteristic of design activity more generally, that makes design distinctive as an approach to complex and ill-defined situations such as wicked problems. Whereas forms of problem solving that rely on analysing the problem or setting goals at the outset are inapplicable with wicked problems, designers bypass such difficulties by moving quickly to the making of proposals and reflecting on and evaluating these to explore and understand the constraints and opportunities of the situation. This allows them to co-evolve their understanding of the situation with their ideas about how to change it, addressing questions of which problem to address (features 8 and 9) and how it is to be formulated (feature 1) as part of this process (Cross, 2007; Dorst, 2015; Dorst & Cross, 2001).

It follows that designers' proposals and any claims made about them are always contestable and provisional (features 2, 3, and 4). While this is a concern given the impact of designers' decisions on others (feature 10), it can also be thought of positively in the light of this way of working, as leading to more open-ended explorations and new possibilities (Glanville, 2011), similarly to how conversation, having no predetermined script, develops in directions that cannot be foreseen. Indeed, this tendency towards the new is crucial given that, with wicked problems, each situation is unique and there is no enumerable list of possibilities from which to select a solution (features 6 and 7), and also because designers are concerned with the new in any case, in the transformation of existing situations and the aesthetic qualities of novel environments.[6] If the situation could be resolved with certainty, there would be no need and no opportunity for what design can bring. Indeed one of the characteristic activities of designerly problem solving is the tendency to treat even straightforward problems as if they were ill-defined (Cross, 2007, p. 100; Thomas & Carroll, 1979), a strategy that both opens up new possibilities and guards against the prema-

[6] "Delight" has been one of the key characteristics that architects try to achieve in their designs, as noted in the earliest surviving text on architecture, Vitruvius' *Ten Books on Architecture* (I.iii.2, trans. 1624). Glanville often associates this with novelty (e.g. Glanville, 2007b, p. 1178). In this he follows Pask's (1969, 1971) approach to aesthetics, which stresses the importance of novelty or surprise value.

ture taming of problems. Thus, while there are no universally applicable methods for wicked problems (feature 7), the conversational way in which designers work is a transferable strategy through which specific responses can be developed for each unique situation.

While designers cope with many of the challenges of wicked problems as a matter of course, the way that every solution to a wicked problem is a one-shot operation (feature 5) remains a significant difficulty, as does the tension between the contestability of designers' proposals and the significance of their impact on others (feature 10). These difficulties are particularly the case at larger scales, such as with architecture or urban design, where there are significant difficulties in identifying affected stakeholders. As one cannot (usually) build a building just to test out a possible solution,[7] designers work around this by using media, at various levels of abstraction, to develop and test their ideas before implementing them. This reliance on media can lead to significant difficulties compared to scales where prototypes can be tested more fully, such as the criticism of a building as one that "looks good on plan" and the way that the abstractions of architectural drawing conventions distance design decisions from the situations that they create and impact (Till, 2009). Yet, it is always some form of design—and so some sort of modelling through media—that we turn to when faced with one-shot operations in order to try to predict how our actions will work out, including their effects on others. The question of how to manage or mediate this asymmetrical agency—where the taking of design decisions is distanced from those that these decisions affect—is a central issue at stake in how design is practised and one I return to below.

Wicked Problems and Ethical Dilemmas

Rittel and Webber's original account of wicked problems was concerned with ethical issues, and this is part of their difficulty.[8] The connections are multilayered. As design processes and their outcomes tend to be interwoven with ethical concerns of one sort or another (e.g. Chan, 2015; Harries, 1997; Lloyd, 2009; Sweeting, 2016b; van de Poel, 2001), ethical questions or criteria may be part of what constitutes the wicked problem, either in terms of straightforward constraints or questions that are themselves matters of ongoing debate amongst those they concern. In addition, wicked problems raise ethical considerations even where these are not apparent within the substance of the problem itself. For instance, even those design questions that could be regarded as being solely matters of technical efficiency or aesthetic

[7] A notable exception to this is the work of Cedric Price. His prominent but unrealized Fun Palace project, to which Pask was a significant contributor, can be thought of as a proposal for an ongoing enquiry into its own purpose. Price regarded architecture as "too slow to be a problem solver" and sought to embed the design process in buildings themselves (Price, 2003, p. 136).

[8] Note, though, that the wickedness of wicked problems is not meant to imply any ethical wickedness but, rather, complexity (Rittel & Webber, 1973, pp. 160–161).

preference may have unforeseen impacts on other parts of the system (feature 8), while the way in which any question is addressed raises ethical issues of its own in terms of the asymmetry of agency between stakeholders (feature 10). In addition to these connections to ethics in terms of content, there is also one in terms of structure. In their contestable and uncertain framing (features 3, 8, and 9), wicked problems resemble those dilemmas with which normative ethics is both most concerned and confused.[9] This is not to say that all ethical questions are wicked but that with tame questions in ethics being easily solvable, it is with the wicked ones, those that present us with dilemmas to which there is no clear answer, that we look to normative ethical theories for guidance.

Ethical dilemmas typically involve conflicting premises and criteria, such that what action to take is contestable. Alasdair MacIntyre (1985, pp. 6–7), for instance, describes a series of familiar contemporary debates that are characterized by the clash of contradictory positions that follow from premises that are in themselves reasonable but which are incompatible with each other. It might be countered that the contestability of such situations may be resolved through one theory or another. For instance, we might make the conflicting premises commensurable with each other, either through some form of consequentialist calculus, such as in utilitarianism, or through a unified conception of the purpose of human life, such as proposed by MacIntyre. Alternatively, we might apply moral rules discerned from rational thought, divine revelation, or tradition. To be sceptical towards such approaches is not necessarily to commit to relativism or to an equivalence of all values, which, indeed, can be thought of as further attempts to remove contestability. As Isaiah Berlin (1998) has cautioned, our tendency to assume that there will be one solution to such questions can obscure the way that different goods may be incompatible with each other. Moreover, the plurality of ways to *tame* (using Rittel and Webber's term) ethical dilemmas is part of their difficulty. We may have many ways in which to come to definite answers to ethical questions, but these follow from different characterizations of the same situation and so lead to quite different proposals for how to act. We have no authoritative way to choose between these approaches: As with wicked problems in design, proposed solutions may be both better and worse in different terms, and the "choice of explanation determines the nature of the problem's resolution" (Rittel & Webber, 1973, p. 166).

The remaining features of wicked problems are also relevant. While there is a tendency in ethical philosophy to characterize such dilemmas as forced choices between competing alternatives in order to clarify what is at stake between different principles, choices are rarely so clear in practice and one can, and may need to, devise new ways forward or improve upon existing options (features 2 and 6) (Whitbeck, 2011). While precedent may be a useful guide to many complex ethical situations, the contestability of ethical dilemmas is such that which precedent to

[9] Whitbeck (2011) has put forward a similar analogy in terms of the ill definition of design questions and practical ethical reasoning. My account here supports this view but takes a different path, looking to underlying parallels in terms of structure and addressing normative as well as applied ethics.

invoke is itself a matter of dispute, and there is no guarantee that it would have the same outcome in any case (feature 7). We clearly cannot work at ethical questions by trial and error or empirical experiment because of the impact this has on others (we have no right to be wrong; feature 10) and also because any action changes the substance of the question (each situation is a one-shot operation; feature 5). Moreover, the complex interrelation of different situations means that resolving one ethical problem may raise further ethical questions to consider or cause unexpected consequences elsewhere or in the future (features 1, 4, and 8).

Even if it is argued that the incommensurability of many ethical dilemmas is circumstantial and could be clarified, it is evident from the ethical challenges that designers face that at least some ethical problems are wicked. That this is so challenges the idea of normative ethics itself. While normative ethical theories seek to give us definitive guidance, or at least clarification of what is at stake in some situation, they cannot do so with wicked problems, which have no right answer or definitive formulation. While it could be argued that this is only a quality of situations as we encounter them, and that normative ethics deals with questions of what is right in principle rather than practically what to do in some particular situation, the idea of what is good conduct must refer to an action that it is possible to take in a situation as we find it. To separate ethical theory from the actuality of circumstance assumes an unworkable objectivity, akin to the sorts of linear approaches to design that Rittel and Webber critiqued as only possible given an implausibly complete description of the situation.

Indeed, neither of the two most commonly articulated positions in normative ethics, consequentialism and deontology, can in principle guide us with wicked problems. The reasons for this mirror the limitations of attempts to rationalize design using deductive problem solving or techniques such as optimization. Consequentialist ethical theories involve the optimization of our actions against a predefined overall goal. Yet, given that a wicked problem has no definitive formulation, there is no clear goal against which to optimize. While designers are rarely short of criteria that can be applied, these are often incommensurable or even in direct conflict with each other due to limitations on space or resources with the result that the attempt to optimize some rather than others is problematic. We may be able to optimize individual aspects, such as structural performance, environmental efficiency, or cost, but there is no way in which we can take this approach to the design task as a whole because of the incomplete and changing nature of its criteria and aims and the tendency of these aims to be in conflict with each other in any case. Moreover, it is not clear how one may evaluate resolutions to wicked problems in terms of their consequences: Even if the end does justify the means, it is arbitrary what we take as an end as there is no ultimate test (feature 4) and the consequences of actions can be manifold and unpredictable (feature 8). This is in part because of the complexity of design tasks, but also because of the way that design's purpose is closely related to our own—as noted in accounts of architecture such as those of Nicholas Negroponte (1970, p. 69; 1975, p. 135), Pask (1969), and Dalibor Vesely (2004, p. 5)—and so to the ambiguities of our own goals. Negroponte, the concerns of whose Architecture Machine Group parallel many of those of Rittel and Webber, goes as far as to say that optimization is "extremely antagonistic to the nature of architecture" (Negroponte, 1975, p. 189) and compares design to the game of croquet in Lewis Carroll's (2001, pp. 99–114) *Alice's Adventures in Wonderland*, where the game is continually and unpredictably changing as all its elements are alive and so learn and adapt as play continues (Negroponte, 1970, p. 69). Likewise, while deontological approaches to ethics require that we conform to predefined rules, such an approach cannot be applied to wicked problems. The situation of a wicked problem is not fully known and is, in any case, transformed into a new one through designers' action with the result that, even if one had rules to follow, it is not clear which rules to apply. As Negroponte has put it: "any axiom or rule can find a situation where it will fail or generate disaster when blindly executed as a truism" (Negroponte, 1975, p. 33).

While deontology and consequentialism may still have much to contribute in particular circumstances, the sorts of reasoning on which they rely resemble approaches that are unworkable with wicked problems and may even be counterproductive: With wicked problems "proposed 'solutions' often turn out to be worse than the symptoms" (Churchman, 1967, p. B-141). This has significant consequences for design ethics, and, given the parallels between wicked problems and ethical dilemmas, we should also be wary of the claims of these and similar theories to guide action in complex ethical situations more generally.[10] Ethical theory has been criticized for its tendency to treat ethical questions from the point of view of an idealized external spectator or judge rather than from that of the agent within the situation (Hampshire, 1949; Varela, 1999; Whitbeck, 2011). In so doing it echoes the weaknesses of the design methods movement in its attempt to rationalize design, as critiqued by Rittel and Webber. In moving away from the attempt to base design upon science, theorists such as Cross (1982), Glanville (2014c), Schön (1991), and Bruce Archer (1979) developed an understanding of design's disciplinary foundations in its own designerly terms. Glanville (1999, 2014c) went as far as to argue that an understanding of design might inform science, inverting the more usual hierarchy between the two. The similarities between wicked problems and ethical dilemmas, together with the confidence with which designers approach the former, suggest that a similar approach might be taken in the case of design and ethics. We might therefore look to design to inform ethics as well as vice versa. One avenue for this is that of practical ethical reasoning. Caroline Whitbeck (2011) has suggested that design might serve as an example for the sort of practical problem solving that has been neglected in ethical theory. Some of the specific techniques that designers use to structure problems might even be directly applied to aspects of applied ethical questions (Dorst & Royakkers, 2006). The parallels between ethical dilemmas and wicked problems that I have outlined support such suggestions but also open up further possibilities, some of which I explore in the remaining space of this essay.

[10] Consequentialism and deontology are not the only approaches to normative ethics. Alternatives such as virtue ethics, pragmatic ethics, or care ethics are more compatible with wicked problems. However, there still remains the issue that different approaches imply different responses and there is no way to resolve between them.

No Way to Be Right, No Right to Be Wrong

As noted above, designers have "no right to be wrong" (Rittel & Webber, 1973, p. 166) because of the significant impact their actions have on others, yet they have no way to be right, as design questions have no right answers or ultimate tests. While the other features of wicked problems are all ones that designers deal with largely as a matter of course, the asymmetry of this situation—between those who have agency over design decisions and those who live with their effects—leaves designers in a bind from which they cannot easily escape. This asymmetry is not problematic in itself. Where some question either has an uncontroversial right answer or where it can satisfactorily be regarded as a matter of a designer's preference, its asymmetry is of little consequence. For instance, there are many design decisions where designers are free to exercise their judgement in one way or another, while various technical questions, such as the variety of roofing material that is specified for a building or which of various possible structural systems is employed, can be resolved in any of various ways so long as they work. These are examples of tame problems, and while they may involve ethical issues, for instance, regarding professional ethics, they do not present us with the sort of ethical bind with which I am concerned here. However many design questions are not satisfactorily a matter of preference as they impact on others in ethically significant ways, but neither can they be resolved objectively, with the result that the relationship between designers and those they design for is paternalistic. While not all decisions that designers encounter are like this, many are and there is not a clear boundary between those that are and those that are not. Indeed, even the choice of roofing material can involve much wider implications.

This asymmetry is especially present in designing architecture, on which I focus here for this reason, as well as because it is the discipline in which I myself sit. Buildings are of a scale both intimate enough to be entwined with everyday life and large enough to be unavoidable. The design of architecture is therefore not solely a matter for its designers. Yet, it is largely for the same reason—architecture's impact on others—that designing architecture involves wicked problems and cannot be settled objectively. Despite not being a matter of personal preference, in many instances it can only be a matter of opinion. While in similar situations in everyday contexts we will often try to find some consensus amongst all those who will be affected by the decision, such an approach is impossible to achieve in designing architecture where we cannot possibly consult every stakeholder (consider, for instance, the passer-by and the future user), let alone find agreement amongst them. While one can try to bridge the asymmetry of the design process, this can be difficult to achieve and brings its own problems. Strategies such as self-build, user-customization, or responsive technologies rearrange the relationships between designer and designed-for, but similar questions reappear regarding the design and implementation of such processes and systems. Participatory forms of design, such as those developed by Rittel himself (Werner & Rittel, 1970), look to address this. While such approaches have proved valuable in specific contexts such as healthcare (e.g. Sanders, 2016), they are difficult to apply more generally in architecture because of its wide impact and are often regarded as being in conflict with design, either as an amelioration of it or a radical innovation. In any case these approaches do not always lead to genuine participation or significant interaction. Sometimes consultations are participative in appearance only, while even the most genuine of attempts can struggle because of the difficulty of the task. In particular, they can fail to take account of stakeholders who are less able to articulate themselves or who are as yet unidentifiable, an important consideration as a building tends to outlive its initial users and clients. While there are various ways in which this asymmetrical relationship can be arranged, it is an inevitable part of designing architecture, something to be coped with rather than solved.

This ethical challenge reflects back on ethics itself, wicked problems being not just analogous to ethical dilemmas but also involving them. In the same way that it is not just the outcome of a design process that is of ethical concern but also the way in which that process is conducted, so too it is the way we speak and reason about ethical questions not just their resolution that is ethically consequential. That is, while ethics is a reflection on good ways in which to act, its discourse is itself an activity and so something to which ethical considerations and questions apply. It is not common to turn ethics on itself in this way. As normative ethical theories and moral codes are put forward on the basis that they give guidance as to ethically good actions, they do not invite reflection on how they themselves are discussed or propagated, with such issues tending to be hidden under the catchall of application. Yet, to put forward an ethical theory or moral code can involve a similar bind to that faced by designers in encountering wicked problems. In addition to being significant in its intended impact, ethical reasoning is often also contestable (as discussed above) and becomes asymmetric where claims are made on others. The proponents of a moral code or ethical theory understand what they put forward as being true, removing one element of the bind. Yet with wicked problems—and so with many of the situations where designers seek ethical clarification and with some of the central questions in ethical theory itself—all resolutions are contestable, and claims made on others therefore have a tendency to become moralizing or paternalistic.

In addressing this sort of self-reflexive topic, it makes sense to turn again to cybernetics, a field that has often been concerned with those situations where a domain is applied to itself. This has included its application to its own practice in the development of the "cybernetics of cybernetics," or "second-order cybernetics," as suggested by Margaret Mead (1968) and developed by von Foerster (1995, 2003a) and others in ways that have established connections to ethical concerns. Indeed, it is consistent with von Foerster's overall project to understand his (von Foerster, 2003c) approach to ethics in terms of the application of ethics to itself.[11] Von Foerster stresses our interdependence with the world and our resulting responsibility for the claims we make about it and the actions we carry out within it. We cannot

[11] This aspect of von Foerster's thinking, where domains of research are applied to themselves, has recently been re-emphasized under the heading of "second-order science" (Müller & Riegler, 2014; Riegler & Müller, 2014, 2016).

view the world independently of our involvement, this being a contradiction in terms requiring that "the properties of the observer be left out of any descriptions of his observations" (von Foerster, 2003c, p. 293). He goes on to criticize the articulation of moral codes as making claims that, without an independent perspective, cannot ultimately be justified, and so as forms of moralization where we are concerned with what others should do at the expense of addressing our own responsibilities. Von Foerster suggests that we avoid articulating ethics to others and, instead, keep our ethical consideration implicit in our actions, putting ethics into practice rather than words.

While von Foerster's suggestions are a rich source for ethical reflection (and well worth exploring in more depth than the brief summary I have given here), there are situations where it is difficult to see how such a stance can be maintained. There are times when ethics needs to be made explicit: where not doing so would lead to acquiescence rather than responsibility, where our responsibility includes responsibility for others and so cannot be confined to the personal, or where our actions articulate ethics whichever way we compose our language. To take designing a building as an example, we cannot in the end keep ethics implicit because architecture itself is an articulation of a way of living (e.g. Chan, 2015; Harries, 1987, 1997; Sweeting, 2016b). Indeed, intervening in the lives of others is the very point of the discipline: One would not want an architecture that was not a significant intervention in the world, creating new possibilities in some way. In design and similar situations, we cannot avoid making ethical ideas explicit; nor can we isolate our own responsibilities from those of others. Even to take an approach of enabling different possibilities, for instance, through the design of flexible or customizable spaces, is to take a specific position with concrete consequences for how others are to live. In the context of design and other similarly complex social situations, von Foerster's position can therefore seem idealistic. Yet, the example of design can help extend as well as challenge von Foerster's position, as I discuss in the next section.

Implicit Ethical Questioning

Designers' approach to wicked problems can be understood as a way of coping not just with their complexity but also the ethical challenge that their asymmetry presents. Understood in terms of cybernetics, conversation coincides with, and can even be said to require, ethical considerations, without which the interaction on which it is based cannot occur (Glanville, 2004b, 2005; von Foerster, 2003b, 2003c, 2003d). Likewise, with design being a form of conversation, ethical considerations are embedded in its core activities, along the lines of von Foerster's suggestion that we keep our ethics implicit. In this interpretation, the call to keep ethics implicit applies not just to values or standards of conduct but also to the consideration and questioning of such values and standards. There are three aspects to this I stress here: (1) concern for others, (2) personal responsibility, and (3) questions regarding purpose.

Conversation depends on our concern for others. We need to listen carefully to the contributions that others make and take them and their views into account in our own (Glanville, 2001, 2004b; van Ditmar & Glanville, 2013). While we tend to think of listening primarily as a matter of how to act in an ethically good way in a conversation, it is also a core practical requirement of participating in one. Because meanings are not directly transferred in a conversation, we are responsible not just for what we say but also for how we understand what we hear. Without listening there is no interaction and so no conversation, only monologue or a group of monologues; the conversation cannot move on, and nothing new arises in it. Part of listening is trying to understand and learn from other participants, but we also learn about our own ideas, and ourselves, by trying to understand how we have been understood. We look "through the eyes of the other" (von Foerster, 1991), considering others and how they consider us.

It must be said that designers are not always great listeners. The attitude that the designer knows best, whether because of his or her subjective genius or technical expertise, still persists in how they sometimes present themselves or are treated by others. It was against this view that Rittel and Webber developed their account of wicked problems, and while it remains common to characterize designers as experts, to do so runs counter to the conversational core of design activity. Indeed, accounts of designers as experts can obscure where their expertise lies. In addition to the conversations that designers hold with themselves, such as through sketching, the conversational structure of design activity also includes the face-to-face conversations designers hold with others, such as their regular interactions with peers and colleagues, conventional consultations with various stakeholders, and more ambitious forms of participation or codesign. While participatory processes are often considered as external to design, understanding design in terms of conversation suggests that such methods are related to core aspects of how designers work and even to ways in which they work on their own. Just as in a conversation we look through the eyes of others, so too designers use drawings to "walk through" their proposals from the point of view of those for whom they are designing, many of whom, such as the future users of a building or its passers-by, they will not be able to meet, let alone consult. In this way, even designers' dialogue with themselves, such as through drawing, can be understood as an ethical and participatory activity, involving care for others, as well as an epistemological or practical one.[12] Mirroring this, the conversations that designers hold with other stakeholders are not solely attempts to involve others in what will affect them but also part of how designers learn about the situation in which they act. Therefore, while participation with others is often viewed as an addition to design, it can also be understood as part of designers' own explorations, analogous to the conversations they hold with themselves via drawing. This is not to say that designers are always successful in incorporating others or always try to do this. There are many other dynamics in design

[12] While the conventions of architectural drawing can be rightly criticized in this context for their abstraction (e.g. Till, 2009), this is something addressable through the redesign of these conventions, the media in which they are presented and the way they are used.

that run counter to this, such as the enduring myths of designers as geniuses or experts or the tension between the conversational process of designing and the linearity of procurement and construction. Yet, that core aspects of how designers work are conversational in structure means that we can think of ethical concern for others as integral to design activity rather than leading to limitations on it.

In addition to listening, it is an equally important aspect of conversation that we contribute actively in what we say. We cannot participate in conversations objectively or passively if they are to be conversational because the turning of a conversation is driven by the differences between the contributions of the participants. If we are too passive, for instance, by only affirming what is said by others or doing no more than responding directly to what we are asked, then a conversation either doesn't go anywhere or descends into what is effectively a monologue, or pair of monologues, where though we may still be responding we are no longer interacting. Conversations have no predetermined script. Where there is a script, and to the extent that there is, it is no longer a conversation. There are always different paths that we can take because how we respond to what others say is not determined by what they have said. Indeed, because meanings are not transferred, we are responsible not just for how we respond but for how we understand what we respond to. If we are to sustain conversations or similarly interactive processes, we need to contribute to them in ways for which the responsibility is ours, and we cannot excuse our actions as having been determined by external pressures (Glanville, 1995, 2004b; von Foerster, 2003c).[13]

Similarly, designers cannot work passively or objectively with wicked problems as there are no right answers to be deduced, no overall goals to be optimized, and the criteria against which proposals are to be measured are known only in part at the outset. While designers are sometimes presented or present themselves as impartial or technocratic arbiters between different stakeholders, to treat wicked problems objectively is either to get nowhere or to work with some criteria rather than others in a way that is distorting or arbitrary. Where designers act passively, in rigidly following the demands of a brief rather than putting them in question, this gives nothing to those that they design for, just as staying silent in a conversation does not help it to flourish. This is reflected in Denys Lasdun's (1965, p. 185) oft-quoted summary of the role of the architect as "to give the client, on time and on cost, *not* what he wants, but what he never dreamed he wanted and when he gets it, he recognizes it as something he wanted all the time." It is not enough to fulfil the brief because it will contain ambiguities, inconsistencies, and opportunities that are only brought to light in the design process. Indeed, Negroponte has characterized the design process as, in part, the procurement of the information missing in the brief (Negroponte, 1970, p. 119; Negroponte, 1975, p. 34). Where designers are working in a truly exploratory manner, Lasdun's statement should apply *to them* as much as to their clients.

[13] Although Glanville (2004b) does not place responsibility under conversation, his discussion of it in terms of other cybernetic processes is compatible with conversation.

This does not mean that design questions are to be resolved arbitrarily or subjectively. As discussed above, design questions are full of complexly interacting criteria, constraints, and contingencies as well as responsibilities towards others. Yet, these are not fully established at the outset, and designers need to actively seek out and establish even the most rigid of constraints. As Rittel and Webber (1973, p. 161) note, "it becomes morally objectionable for the planner to treat a wicked problem as though it were a tame one, or to tame a wicked problem prematurely, or to refuse to recognize the inherent wickedness of social problems." Given that wicked problems are defined by attempts to resolve them, designers are ultimately responsible for how they understand and characterize the extent of their own responsibility. Their action formulates what they treat as within their scope and what as outside; which constraints and criteria they challenge and which they accept; and the stance they take towards the more explicit ethical questions involved. This questioning of responsibility will often be explicit in the reframing of questions, but is also implicitly embodied in the conversational form that design activity takes, whether in terms of sketching or face-to-face dialogue with others. Through this, designers actively reformulate the situation and their understanding of it, working out where their responsibility lies. Indeed, while Lasdun's remarks quoted above are sometimes interpreted as a claim to expertise, in the same article, he goes on to stress the importance of interacting with others, noting that the "worst work our office has ever produced" is the "competition work where there is a programme which is half-baked and there is no exchange of ideas" (Lasdun, 1965, p. 195).

Speaking and listening complement each other, enabling conversation to turn around between the perspectives of different participants. The resulting circularity allows a purpose to be pursued, such as communicating a message or reaching an agreement on future action. Purposeful activity such as this is a central concern of cybernetics, especially so in its early development (Stewart, 2000), and this is reflected in the name of the field, which Norbert Wiener (1961) derived from the Greek word for steering. This aligns closely with design, which is purposeful in seeking to achieve change in the world, and also with ethics, in terms of the pursuit of the good. The proto-cybernetic paper written by Wiener, Arturo Rosenblueth, and Julian Bigelow defined purpose in terms of action directed towards a goal, understood as "a final condition in which the behaving object reaches a definite correlation in time or in space with respect to another object or event" (Rosenblueth, Wiener, & Bigelow, 1943, p. 18). This is an adequate characterization for many examples. Yet, as Richard Taylor (1950) responded, this conception of purpose as striving towards a definite final condition does not account for vague or unsuccessful activities that are still goal-directed although no goal exists, such as "a man groping about in the dark for matches which are not there, but which he erroneously believes to be near at hand" or how "the alchemist can seek the philosopher's stone, the knight can seek the Holy Grail" (p. 329). To these examples can be added both conversation and design, whose goals tend to shift and change as they are pursued. Indeed, Taylor's comments anticipate a richer conception of purpose as would develop in cybernetics, which Andrew Pickering (2010, p. 18) characterized as a concern for forms of "forward-looking search."

One way to understand open-ended purposeful activities, such as design and conversation, is in terms of the relation between their internal and external goals. In the eponymous cybernetic example of steering, rather than understanding the destination we are steering towards as the goal, defining our action in terms of something external to it, we can equally understand the purpose of steering as staying on a steady course in response to changes in the environment—and of learning how to improve at this—and so as internal to our action (Sweeting, 2015b). This is not to say that if the goals of an action are internal, it will not also involve external goals, or we must choose between these two sorts of goals. Indeed it is the pursuit of the internal goal of being on course that allows the external goal of the port (and of alternative destinations) to be pursued, while it is the journey to the port that gives the internal goal of steering its relevance and context. While activities such as design or steering a ship are concerned with external goals in effecting change in the world or reaching a destination, these can only be pursued via their internal goals. Maintaining a steady course allows the steersman to respond to changes in the environment and also to change direction to head to different ports. The ends at which design aims cannot be fully defined in advance because new understandings and possibilities, and with them new criteria, are created during the design process as the situation is explored. By sustaining the conversational processes through which the project is framed and given direction, designers question their current goals and develop new ones, allowing them to achieve ends that were not conceivable at the outset. Where design is understood only in terms of the pursuit of a given external goal, what is special about it as a response to wicked problems is lost.

In consequentialism, an ethically good action is one that maximizes its good consequences according to some fixed external goal. In addition to the various difficulties of this in practice, especially with wicked problems as discussed above, it follows that any means could be justified if it achieves the greatest good overall, opening it up to criticisms such as those of G.E.M. Anscombe (1958). By contrast, in the *Nicomachean Ethics*, Aristotle understands the ultimate human goal as that of *eudaemonia* (I.7), usually translated as "the good life" or "human flourishing," something intrinsic to and inseparable from the very action of living. Pursuing such a goal develops new understanding and possibilities, reformulating external goals in the process. MacIntyre (1985, p. 219) defines the good life as a form of "quest": "the good life for man is the life spent in seeking for the good life for man." This aligns closely with the conversational way in which designers cope with wicked problems, addressing not just how to achieve their goals but also implicitly questioning what those goals are and what they could be.

We may disagree with the specific ways that designers interpret their responsibility, consider others, or question their goals. Designers do not always respond to these or other ethical issues effectively, nor is design practice always ethically good, as is clear from the troubled legacy of much architecture that has been put forward in heroically ethical terms, as well as from the contestability of design decisions discussed above. Yet, design and ethics are deeply intertwined. There is a need for designers to consider others, take personal responsibility, and pursue internal purposes for both designerly and ethical reasons. These considerations are latent in design activity, even, and perhaps especially, when designers are not explicitly addressing ethical issues, and so design ethics need not be understood in terms of external limitations or competing priorities. Moreover, design suggests ways that we might cope with ethically complex situations in other contexts. While von Foerster's suggestion that we keep our ethics implicit can appear idealistic, it is significant that designers achieve this, at least in part, in what are complex and often highly charged circumstances. In situations where debate over the right course of action is unresolvable or counterproductive, we might therefore follow design's example in looking to implicit forms of ethical questioning. It is striking that the two most common forms of normative ethical theory—consequentialism and deontology—exclude the sort of implicit ethical consideration that I have noted to be present in design. In following predefined rules or optimizing against set goals, one cannot take the views of others into account, take personal responsibility for one's action, or question the purposes at which one aims. In having adopted such approaches, one's course of action is already set. This accounts in part, I suggest, for what MacIntyre (1985, p. 8) has observed to be the "shrill tone" of modern ethical debate, something which is in desperate need of reform.

Conclusion

In this essay I have put forward a way of understanding design and ethics in mutual terms. I have drawn on systemic approaches to design and ethics in order to build this connection and used the history of the relation between systems thinking and design as a pattern to follow. By identifying similarities of structure between ethical dilemmas and the wicked problems that designers face as a matter of course, I have argued that design can contribute to ethics as well as vice versa. Developing one aspect of this, I have identified ethical considerations that are implicit within core aspects of design activity. These enable designers to cope not just with the complexities of wicked problems but also with the ethical challenges that follow from their asymmetry.

This has a number of consequences for how we might approach ethical questions in design and elsewhere. The relationship between design and ethics need not be seen, as is often the case, in terms of trade-offs between the two or as the application of theories with which to correct design practice. Where design discourse has sought to inform itself by importing theories from elsewhere, this has often had the effect of obscuring or distorting what is special about design activity in the first place (Glanville, 2004a, 2014a). If this is to be avoided in design's encounters with ethical theory, the ethical qualities already implicit in design have an important role to play in mediating between the two. Moreover, that designers integrate ethical considerations implicitly into their thinking, and do so in even complex and ethically charged circumstances, provides an example for how we might cope with the ethical demands of other complex situations, including some of the ethical dilemmas that arise within ethical discourse itself.

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On the Resilience of Sociotechnical Systems

Eloise Taysom and Nathan Crilly

Abstract When designing or redesigning sociotechnical systems, it is often required that those systems be more "resilient" as a result. However, exactly what is meant by resilience in these contexts is unclear. To design resilient systems, we must first be able to answer a number of questions, including: Should a resilient system change to accommodate influences or stay the same? If the system changes, where should this change take place? How do we decide which system, or subsystem, to make resilient? For any given system, answering these questions requires engagement with different stakeholders, allowing a conversation to take place that typically spans different disciplines. However, resilience is a difficult concept to communicate about because terminology is not used consistently across, or even within, domains. This presents a challenge for designers wishing to elicit or understand stakeholders' requirements for the systems that they are concerned with. To address this, we conducted a workshop with stakeholders working in different areas of academia, industry, and policy who are concerned with the resilience of sociotechnical systems. The aim of this workshop was to identify what stakeholders might want to convey about resilience and what would help them to communicate effectively. We identified three main characteristics of resilience and three system features that are critical to communication about resilience. These are all illustrated with a diagrammatic framework that was developed from real system examples given by the participants. From the data we propose a set of distinctions that offer a starting point for discussions about resilience with diverse stakeholders.

Introduction

The world we live in is increasingly complex, interconnected, and unpredictable. We face social and technological challenges, which must be overcome through the maintenance and redesign of existing systems, as well as the design and integration of new systems. Each of these systems has stakeholders at different levels and

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across domains, from those governing societies to technical experts working on well-defined tasks. These stakeholders generally want their system to survive, or even thrive, in the face of uncertainty and unexpected influences. To describe this desire, people, from politicians to CEOs, use the word *resilience*.

The concept of resilience is difficult to talk about because it is really an umbrella term for a set of complicated ideas about change. The exact meaning of "resilience" is not clear, and the term is used inconsistently across, and even within, domains. Not only this, but it is applied in contexts where we face systemic challenges, with technical and social systems that are increasingly interconnected. Sociotechnical systems are designed to fulfil a specific purpose at the point they are first implemented, but are also expected to perform well in the future as legacy systems, despite the fact that they change and their environments change. These systems are also made up of parts that have been designed as well as parts that have evolved. This increases complexity and leads to emergent system behaviour, which makes it difficult to predict how a system will respond to influences.

A complex sociotechnical system has many stakeholders. Each of these stakeholders will have a unique perspective on that system, which may be framed by various factors such as their domain of expertise, job role, and personal values. However, no single stakeholder can understand the system in its entirety. To better understand how resilience is interpreted and how it might be communicated, we held an interdisciplinary workshop with experts concerned with the resilience of sociotechnical systems. The participants discussed the resilience of a broad range of systems, at various levels of abstraction and from different disciplinary perspectives. In the workshop, knowledge was transferred across domain boundaries, and we observed the commonalities and differences between how the stakeholders communicated about resilience. To understand and represent the data, we also developed a diagrammatic framework, which can be used to illustrate examples of resilience. This chapter reports on that workshop, proposing a set of resilience characteristics and system identifiers that offer a starting point for discussions about resilience with diverse stakeholders.

To present the findings of the workshop, the rest of the chapter is structured as follows. Firstly, we review the concept of resilience in the literature and relate it to systems principles. Then we introduce the workshop method. The findings are presented in three sections including the development of the framework, the characteristics of resilience that are important in stakeholder discussions, and the features of systems that are important to consider when clarifying resilience issues. The final section concludes the chapter by summarizing the contributions of the workshop.

Background

To refer to the resilience of a system is to make some claim about the way that system responds to change, often a response that leaves the essential identity of the system intact. For example, a diversified public transportation system can demonstrate resilience by continuing to move people effectively around a region despite being influenced by severe weather, government policy, and the expansion of the suburbs. Resilience is an important concept in many domains and is used to understand the behaviour of organizations (Sheffi & Rice, 2005), cities (Campanella, 2006), social-ecological systems (Folke et al., 2010), and sociotechnical systems more broadly (Pavard, Dugdale, Saoud, Darcy, & Salembier, 2006).

Resilience is evidently a desirable property of many systems, but there is a lack of knowledge in the literature about how to design resilience into systems. This problem is exacerbated by confusion over the meaning of resilience and the different concepts that relate to it (de Weck, Ross, & Rhodes, 2012; McManus, Richards, Ross, & Hastings, 2007; Ross, 2008). This ambiguity makes it difficult to understand the requirements that are being placed on those who create and operate sociotechnical systems and to account for the expectations of their clients or the wider public. The problem is further complicated because systems can be viewed at different levels of abstraction, with one person's system viewed as another person's component or sub-system (Buede, 2000). Stakeholders might be interested in sub-systems or separate systems that interact with the main system in question; these other systems could be social, technical, or some combination of the two. This means that there is a confusion not only about what resilience is but also about what it is that should be resilient and how. There is a lack of research looking at how these concepts are communicated in practice, and therefore it is not clear what questions we should be asking system stakeholders about resilience, so that we can understand what they want and why.

The Concept of Resilience

The word resilience has long been used to refer to the way in which materials and structures rebound or recover from a disturbance. This term was first applied to a systems context in 1973 with Holling's now-seminal work on the resilience of ecological systems. Here, resilience was defined as "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973, p. 14). Over time, the concept of resilience has gained traction across academic domains including disaster risk management (MacAskill & Guthrie, 2014), community studies (Baek, Meroni, & Manzini, 2015), economics (Simmie & Martin, 2010), and psychology (Johnson, Panagioti, Bass, Ramsey, & Harrison, 2016). Although some authors make distinctions between resilience in different domains, for example, engineering resilience as distinct from ecological resilience (Joseph, 2013), these conceptual boundaries are increasingly blurred. Rather, resilience can be seen as encompassing a set of related ideas rather than a single concept (Westrum, 2006).

Generally, the term resilience is used to describe how complex systems, whether naturally occurring or designed, can respond to adverse influences in order to survive or thrive. There are two characteristics of resilience that are prominent in the literature: the ability of a system to resist by absorbing influences (Dovers & Handmer, 1992; Holling, 1973; Timmerman, 1981) and the ability of a system to recover from influences (Pimm, 1984; Timmerman, 1981; Wildavsky, 1988). Resisting and recovering are often seen as part of the same process that occurs when a resilient system is faced with an influence (Amalberti, 2006; Cardona et al., 2003; Haimes, Crowther, & Horowitz, 2008). A system that is able to resist influences without changing in structure or function is described in some fields as robust (Chalupnik, Wynn, & Clarkson, 2013; Fricke & Schulz, 2005; Ryan, Jacques, & Colombi, 2012). However, when resilience is defined as a system's ability to recover, it is not clear if the system changes in function or structure in order to achieve that recovery.

In contrast to a general description of "recovery" or "bouncing back," some authors explicitly refer to the ability of a system to respond to influences by changing in structure or function. The idea of a resilient system being able to "adjust" or "adapt" appears in the literature in the late 1990s and offers two additional aspects of resilience: firstly that a resilient system can respond internally to influences (Comfort, 1999; Haimes, 2009; Home & Orr, 1997; Maguire & Hagan, 2007; Rose & Liao, 2005; Woods & Cook, 2006) and, secondly, that a resilient system can adopt a new state (i.e. undergo a structural or functional change) rather than recover to the previous state (Adger, 2000; Carpenter, Walker, Anderies, & Abel, 2001; Fiksel, 2006; Jen, 2003; Kimhi & Shamai, 2004; Pariès, 2006; Simmie & Martin, 2010; Smith & Violanti, 2000; UN/ISDR, 2004). This characteristic of resilience is related to the system lifecycle properties flexibility and adaptability (Chalupnik et al., 2013; Fricke & Schulz, 2005; Ryan et al., 2012). The terms flexibility and adaptability are often used synonymously to describe all types of system changeability.

The question of how to describe resilience has been debated strongly in the literature. For example, some authors argue that the term is becoming too broad, to the extent that it can be meaningless (Joseph, 2013; Rose, 2007). One reason behind this is that the term is used to describe different types of system facing different types of influences that operate at different levels within the system (Handmer & Dovers, 1996; Westrum, 2006). The conceptual breadth of resilience can also be seen in a more positive light, as a necessary reflection of the complexity of sociotechnical systems. Using a single term across domains means that ostensibly different ideas in different fields of study can be shown to be essentially identical. In either case, we must have ways to talk about different types of resilience.

A Systems Approach to Resilience

The importance of a holistic approach to resilience is evident in the ecological and socioecological literatures. Here we make the case that the same is true in sociotechnical systems. At a low level, it is desirable that technical systems are predictable, reliable, and robust. For example, a car is designed to perform under a set of environmental conditions that have a predetermined range, such as temperature, road surface, and impact forces. A car is designed to be efficient and cost-effective. However, when a car is combined with a driver, the combined system can be resilient, dealing with unexpected external events. In this combined system, the car resists influences, and the driver changes to accommodate influences. Engineers are generally adept at designing systems that resist or recover in response to influences. It is designing systems that change to accommodate influences that presents the greatest challenge. Some researchers have tried to address the challenge of designing changeable technical systems and found it necessary to take a sociotechnical approach (Melese, Stikkelman, & Herder, 2016).

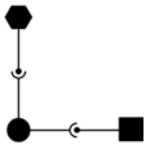
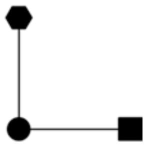
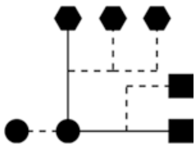
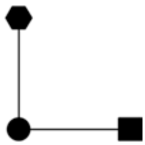
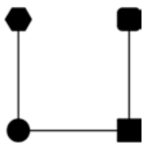
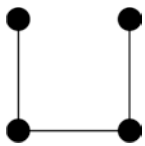
In both design literature and practice, there has been increasing interest in the design challenges associated with sociotechnical systems (Norman & Stappers, 2015). These sociotechnical systems, such as governance, healthcare, and transportation, are often large and complex, spanning across domain boundaries. Their success is usually dependent on the interactions between technical and social sub-systems. Therefore, taking a systemic approach to the design of sociotechnical systems can reveal insights about their structure and behaviour, which would not be apparent if looking at either the technical or social sub-systems in isolation (Behymer & Flach, 2016). Some researchers insist that engineers and designers of technical systems have a moral obligation to consider the wider social systems that they design for or within (Vermaas, Kroes, van de Poel, Franssen, & Houkes, 2011). More generally in systems engineering, by expanding the boundaries of the technical systems we consider, most designed or engineered systems either contain or interact with a variety of people, organizations, economies, and other entities that are often best understood on a sociotechnical basis (Kroes, Franssen, van de Poel, & Ottens, 2006).

The sociotechnical systems that stakeholders must analyse, understand, and improve are often partially designed and partially evolved (de Weck, Roos, & Magee, 2011). This requires stakeholders to grapple with the complexity of systems that they only incompletely understand and to interpret emergent behaviour that was not anticipated (Chen & Crilly, 2016a, 2016b; Frei & Serugendo, 2011a, 2011b). The function and structure of such systems will be perspective dependent. That is, two stakeholders might view the same system from a different level of abstraction and only be aware of some of the social and technical sub-systems that are relevant at that level.

Relating Resilience to System Attributes

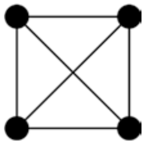
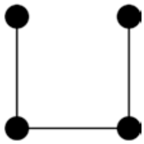
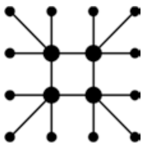
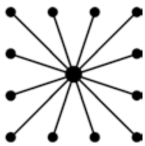
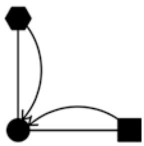
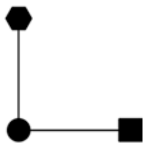
One way to understand resilience in the context of systems is to identify related attributes. These attributes can be built into systems in order to realize certain system lifecycle properties. These attributes can be designed into system architectures, which can be functional, physical, technical, or dynamic operational (Levis, 1999). Table 1 lists some of the attributes that have been linked by authors to increased system resilience in both technical and social systems. Other system attributes listed in the literature are either domain-specific, e.g. "leadership" or "trust" in social systems (Carpenter et al., 2012), or are some variation on the attributes listed in Table 1.

Table 1 Attributes that contribute towards resilience in sociotechnical systems. The diagrams show how a system might differ if it had more or less of the attribute in question

		System example		
Attribute	Description	More of attribute	Less of attribute	References
Modularity	The degree to which a system is segmented into parts or sub-systems that can be removed or recombined in a different way. There are many different types of modularity; however, many authors refer to modularity without defining the type. Modularity can enable the reconfiguration or replacement of parts of a system			Ash and Newth (2007), Baek et al. (2015), Carpenter et al. (2012), and Chen and Crilly (2014)
Redundancy	The presence of duplicate parts or sub-systems in a system that can take over from one another when necessary. Can be functional or structural. This offers a backup option in the event of failure or damage. Redundancy also takes the form of reserves within a system that enable it to recover. In systems that are optimized to perform specific functions, redundancy can be seen as expensive inefficiency			Baek et al. (2015), Biggs et al. (2012), Bruneau et al. (2003), Carpenter et al. (2012), Comfort (1994), Madni and Jackson (2009), and Whitacre and Bender (2010)
Diversity	The number of different types of components with different functions. Increased diversity provides opportunities for the system to change or pathways between components to change. However, uniformity can lower production and maintenance costs in systems			Baek et al. (2015), Biggs et al. (2012), Carpenter et al. (2012), and Fiksel (2003)

(continued)

Table 1 (continued)

Attribute	Description	System example		References
		More of attribute	Less of attribute	
Connectivity	The degree to which components in a system are connected to one another. Increased connectivity can lead to an increase of alternative pathways through a system. This means that influences or their effects can potentially be avoided. It can also lead to the propagation of influences through the system so more parts are affected. Also referred to as openness			Baek et al. (2015), Biggs et al. (2012), Carpenter et al. (2012), Fiksel (2003), Mosleh, Ludlow, and Heydari (2016), and Whitacre and Bender (2010)
Decentralization	The degree to which a system is controlled from multiple hubs within a system, as opposed to centralized, top-down control. This gives sub-systems some degree of autonomy and can increase the speed and accuracy of response to influences			Ash and Newth (2007), Biggs et al. (2012), and McDonald (2006)
Feedback loops	The level of feedback within a system to its constituent parts. This feedback means the system can learn from past events as well as monitor influences and responses			Biggs et al. (2012), Carpenter et al. (2012), and Leveson et al. (2006)

For example, "clustering" is described as the extent to which strongly connected components are grouped into distinct sub-systems, which can help to avoid the negative consequences of connectivity by containing the effects of influences to a single cluster (Ash & Newth, 2007). This is a type of modularity. Similarly, "degeneracy" is a form of functional redundancy where functions in a system can be redistributed amongst different system components (Whitacre & Bender, 2010).

The amount that each attribute increases (or decreases) resilience is dependent on the system, the level within a system the attribute occurs, and the types of influence the system faces. It is not the case that increasing one system attribute will indefinitely increase the resilience of a system. There are trade-offs between designing for robustness and designing for flexibility or adaptability. For example, in resilient organizational systems, these trade-offs might include centralizing control versus decentralizing control, maintaining product quality versus adjusting products to changing needs, and using well-tested technologies versus developing new innovative technologies (McDonald, 2006). Generally, we can say that certain system attributes lead to certain characteristics of resilience. However, these relationships are not straightforward. Also, it is not clear how to apply these theories in practice for sociotechnical systems. The first step towards understanding these issues more clearly is understanding how to communicate about resilience concepts.

Method and Participants

To explore questions about resilience, a workshop was organized by the Cambridge Engineering Design Centre (EDC) and the Cambridge Centre for Science and Policy (CSaP) in December 2014. The selected participants were 21 senior policy makers, academics, and industry practitioners. Although from very different fields of expertise, the participants all worked on complex sociotechnical systems and were concerned with how to make those systems more resilient.

The format of the workshop comprised two chaired discussions lasting 2 h each. The first workshop began with short presentations by four participants from different domains, representing issues related to the resilience of cities, space systems, insurgent groups, and national security. These talks illustrated the broad applicability of resilience to different sociotechnical systems, the different perspectives that can be taken on resilience, and the conceptual and communicative challenges that result from efforts to describe resilience.

Because the workshop stakeholders came from a diverse set of domains, the majority of the discussion referred to systems in the abstract sense, enriched with domain-specific examples. Communication across domains was helped by both abstraction, which highlighted commonalities across apparently disparate systems, and exemplification, which made the stakeholders' points compelling and accessible. Therefore, in discussing the findings for this study, the examples are presented in both abstract and domain-specific forms.

Sample

Table 2 summarizes the workshop stakeholders by field of study and whether they work primarily in academia, policy, or industry (many stakeholders crossed these boundaries).

Table 2 List of workshop stakeholders by field of study or practice

D	Field of study/practice	Academia	Policy	Industry
P01	Design engineering	X		
P02	Human geography	X		
P03	Operations research	X		
P04	Mechanical engineering	X		
P05	Psychophysiology	X		
P06	Biological sciences	X		
P07	National security	X	X	
P08	Science and policy	X	X	
P09	International policy	X	X	
P10	Science and policy	X	X	
P11	Built environment	X		X
P12	Architecture	X		X
P13	Telecommunications			X
P14	Architecture			X
P15	Space systems			X
P16	International policy		X	X
P17	International policy		X	X
P18	Healthcare		X	
P19	Counter terrorism		X	
P20	National security		X	
P21	Science and policy		X	

The participants were all concerned with specific sociotechnical systems, but these were of very different kinds, and different aspects of them were emphasized. For example, the participants discussed the performance of cities (P10), the capacity of industries (P20), the emotional state of professionals (P05), and the operation of insurgent groups (P19). Despite this diversity, strong connections could be observed between how these different systems are thought about and how their resilience is considered.

Data Collection and Analysis

The workshop was recorded and transcribed for analysis, supported by extensive notes taken by two independent observers. The resulting material was analysed, and themes were drawn out relating to what the participants were communicating about resilience and the difficulties they had experienced in doing this. The themes arrived at were discussed between two researchers and compared against the notes and observations of other researchers present in the workshop (Robson, 2011). This analysis process was supported by the development of a diagrammatic framework for representing resilience concepts, drawing together findings from the literature and the workshop data (Umoquit, Tso, Varga-Atkins, O'Brien, & Wheeldon, 2013).

The data was rich in examples given by the participants from their own experiences. Notable examples have been drawn out to illustrate the themes in this study. These are presented as abstracted system descriptions and diagrams, for domain neutrality, using the diagrammatic framework, before being given in the original domain-specific context. The domain-specific examples are paraphrased from the workshop data and are referred to with the participant ID numbers (see Table 2). These participant numbers are also used in the text to indicate how the themes are connected to the data. The workshop was conducted under the Chatham House Rule (Chatham House, 2017); therefore, the identity and affiliations of the participants are not given. The examples given are not direct quotes from any individual but were derived from analysing the discussions between participants.

Analysing the data revealed what stakeholders are trying to communicate when they talk about resilience. The data also suggested ways in which communication about resilience can be improved. The issues raised in the workshop are enriched with real-life examples from the stakeholders' own experiences. These examples are developed from the workshop transcript and used to illustrate each abstract system example.

Developing a Diagrammatic Framework for Resilience

To represent and abstract the system examples that the stakeholders gave in the workshop, we developed a diagrammatic framework. This is based on the findings from the workshop, on what needs to be communicated about resilience, and is informed by the academic literature, on how to represent resilience concepts. In the literature, diagrams already have been used to communicate to an academic audience; however, no existing diagrams were available for capturing resilience discussions between system stakeholders or for communicating across different domains. Our diagrammatic framework was developed to fulfil those two functions.

System Structure

The structural aspects of the framework are shown in Fig. 1. Stimuli that influence a system are shown on the left of the diagram. In engineering systems, *exogenous influences* typically include natural environmental or financial conditions, whereas *endogenous influences* could be component failures or emergent behaviour within the system (Crilly, 2013). Separate from the stimulus is the response shown on the right of the diagram. Changes in the system occur if there is an *exogenous change agent*, which could be a consultable client in a project or a system operator, or an *endogenous change agent*, such as an automated mechanical response.

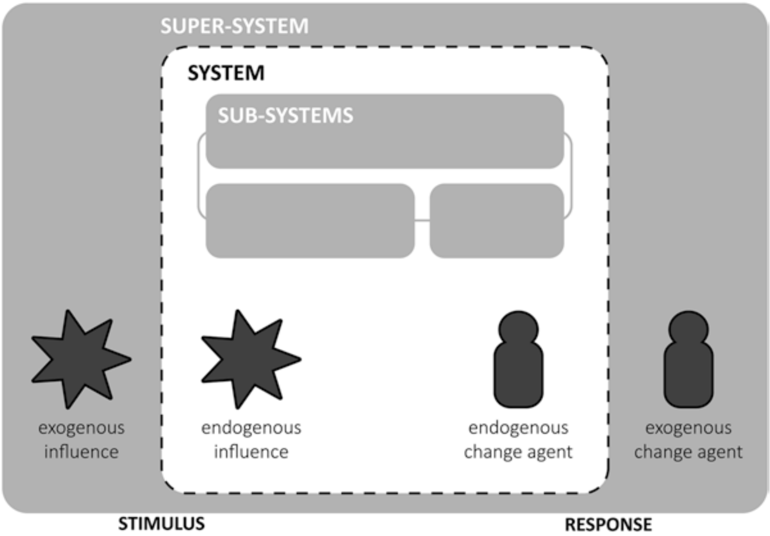


Fig. 1 Hierarchical graphical representation of a system showing stimulus and response

The system structure is shown using three levels of abstraction: *system, super-system*, and *sub-system*. This hierarchy allows changeability to be discussed with stakeholders at different system levels, for example, in the case of achieving a robust system by designing flexible and adaptable sub-systems. In practice the system boundary and level of abstraction will be decided by specific stakeholders depending on their individual perspectives (Maier & Rechtin, 2009).

A set of lifecycle properties based on the structural aspects of the framework is shown in Table 3. This set was formulated using permutations of stimuli and responses alongside the linguistic definitions in the literature. Lifecycle property names have been suggested although, as in the literature, not all stakeholders may share common definitions. As such, we focus here on the varieties of lifecycle properties that might be distinguished and represented, rather than the labelling of those properties. Efforts have been made to consider specific lifecycle properties discussed in this research, but it is not claimed that the diagrams presented are exhaustive or definitive; they are a starting point for discussion.

System Function

The functional perspective in the framework allows us to show how the system's purpose, role, or identity changes over time. This is achieved by using a temporal arrow, which represents the function of the system. The arrow can be used to show situations where, for example, a flexible or adaptable system responds to an influence and redefines the value delivery of the system to meet new challenges. There are three main paths the function arrow can take in response to an influence: The

Table 3 Framework for structural representations of system lifecycle properties

	An exogenous influence stimulates the system but there is no response. The value delivery may improve or degrade but remains within the acceptable threshold values. The form or structure of the sub-systems may change. This is commonly referred to as *robustness*
	An exogenous influence affects the system. An external change agent responds to the influence, enabling a system change. This is referred to as *flexibility*
	As above, an external change agent enables system change, but the influence in this case is endogenous. This is also considered to be *flexibility*. Although a distinction is not generally made between the two cases, it may be useful to do so
	In this instance, an exogenous influence initiates a response from an internal change agent. The change agent enables a system change. This is generally called *adaptability*
	As above but with an endogenous influence. Also referred to as *adaptability*

value delivery does not change (Fig. 2a), the value delivery changes temporarily (Fig. 2b), or the value delivery changes permanently (Fig. 2c).

Combined Framework

Representing both the structural and functional aspects of changeability can be done using the combined framework shown in Fig. 3. The system function is shown as an arrow representing the system progressing through time. The structure of the system can be shown at snapshots in time, at the points where representing the structure is

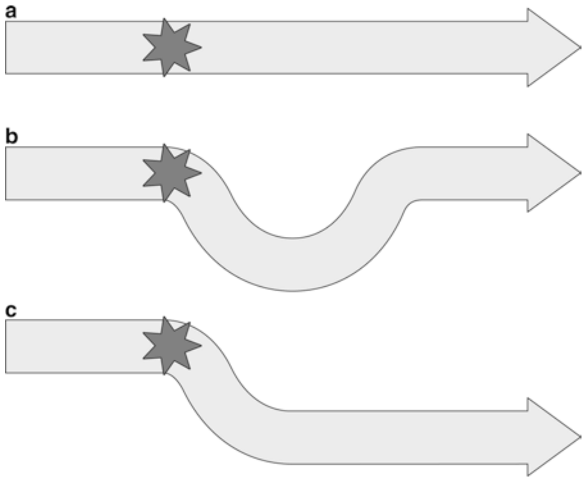


Fig. 2 Arrows showing the function of the system progressing through time as the system (**a**) resists an influence, (**b**) recovers from an influence, and (**c**) changes in response to an influence

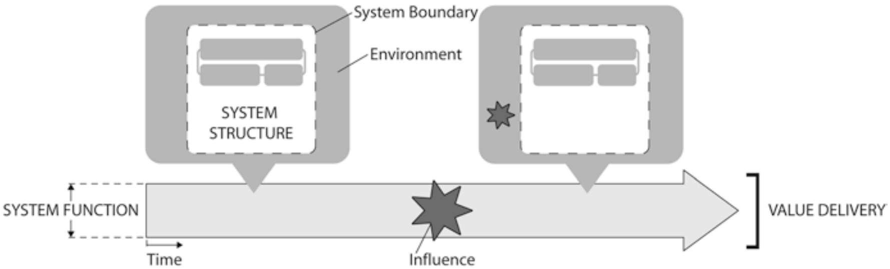


Fig. 3 Combined framework showing the system structure and function

most helpful or when that structure is known (assuming that in a complex system the structure will sometimes be unknown).

How People Talk About Resilience

None of the participants offered formal definitions of resilience in the workshop, but particular interpretations of resilience were implicit in what they said. Generally, these notions of resilience related to how a system responds to influences in order to continue functioning. However, as shown in the literature review, resilience is not a stand-alone concept but instead encompasses a group of system lifecycle properties that relate to both persistence and change. By combining these properties in different ways, three main characteristics of resilience emerged in the workshop:

- R1: Resilience as resisting influences
- R2: Resilience as recovering from influences
- R3: Resilience as changing to accommodate influences

These characteristics of resilience represent the variety of perspectives on resilience discussed in the workshop, rather than a consensus view. Some participants referred to a single characteristic, whereas others saw resilience as encompassing two or more characteristics. Significantly, these characteristics appear to cover all of the various interpretations of resilience in the literature.

Resisting Influences (R1)

The workshop participants considered the system's ability to resist influences as a marker of resilience, reducing the initial impact of an influence or the fragility of the system (P11, P14, P21). The literature review suggests that this characteristic is equivalent to the system lifecycle property robustness. However, as shown in Example 1, an over emphasis on system robustness can lead to missed opportunities.

Example 1 System X is influenced by system Y. System X can (a) resist the influence and remain unchanged or (b) change to accommodate system Y. In the latter case, the structure and function of system X may change.

Example 1 in the context of social sciences: (a) A society (X) sees a group of new people (Y) as a threat to their collective identity so they protect themselves, refusing to let the group become part of their society and resisting change. Is the society being resilient or are they rigid? (P09).

In Example 1, system X could represent a society that resists changing to accept incoming people (Fig. 4a), which can be seen as rigidity rather than resilience. A society that welcomes new people has the potential to increase the functionality of the system, even though it might change the "purpose" of the society (Fig. 4b). The ability to resist change (to be robust) is an important characteristic of resilience, but it is not always desirable. Increasing robustness without considering other aspects of resilience, such as the ability to change to accommodate influences (R3), does not just risk the system becoming rigid, it may also make the system fragile.

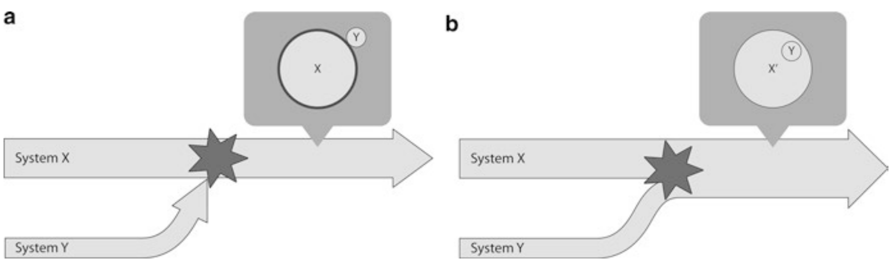


Fig. 4 Diagram showing system X (**a**) resisting the influence of system Y and (**b**) changing to accommodate system Y as a new sub-system

To increase the ability of a system to resist influences, there are two possible approaches: to make things harder to influence or to reduce the impact of influences. The first of these can be achieved by being impenetrable to outsiders who could potentially influence the system (P19). Alternatively, the impact of influences can be reduced or absorbed by strengthening a specific part of the system (P06, P14, P20), for example, by making the nodes of a network robust (P20). This selective robustness is preferable to the whole system being robust and therefore rigid. It is also likely that only some of the system is well understood or accessible; for example, resource flows may be easy to disrupt, whereas physical entities are easier to make robust (P20). Having some vulnerable system components means that small breakages can occur, which allow for change, preventing stress building up in the system until it reaches a tipping point where the system suffers catastrophic damage (P06).

Recovering from Influences (R2)

A robust system may decrease in performance after being subjected to an influence. For example, if an influence reduces functionality temporarily, once that influence is removed, the system may be able to resume normal functionality and recover to previous performance levels. This type of recovery, where the system does not change but has the capacity to recover, can be considered part of robustness. At a certain level of abstraction, the recovery process will not be observable, and the system will appear to be robust, having apparently not changed in structure or function. Equally, some observers will not be able to see there has been any performance loss.

There is however another type of recovery where the structure and function of a system change in response to an influence, but eventually return to the original functions and value delivery. Example 2 shows how during this period of change the system survives by temporarily changing its value delivery.

Example 2 System X has two purposes (P_1 and P_2), which, at the beginning ($t = 0$), can be fulfilled simultaneously by the system. When the system is affected by an influence (I), it adapts to focus system resources on fulfilling one purpose, P_2. Once the influence is no longer affecting the system, the system recovers to resume its previous state, fulfilling both P_1 and P_2.

Example 2 in the context of psychophysiology: An athlete (X) must sustain two purposes to be successful—mental wellbeing (P_1) and high levels of physical performance (P_2). In a bid to maintain their physical performance during a competitive sports event (I), an athlete's mental performance can suffer. Does a resilient athlete maintain both their mental wellbeing and physical performance at all times or have the capacity to recover (P05)?

In this example, an athlete's mental wellbeing is temporarily affected by a competitive sports event but recovers after the influence. The system's athletic function is maintained (physical performance) because it is prioritized over other functions (mental wellbeing). The diagram in Fig. 5 could represent a small section of the

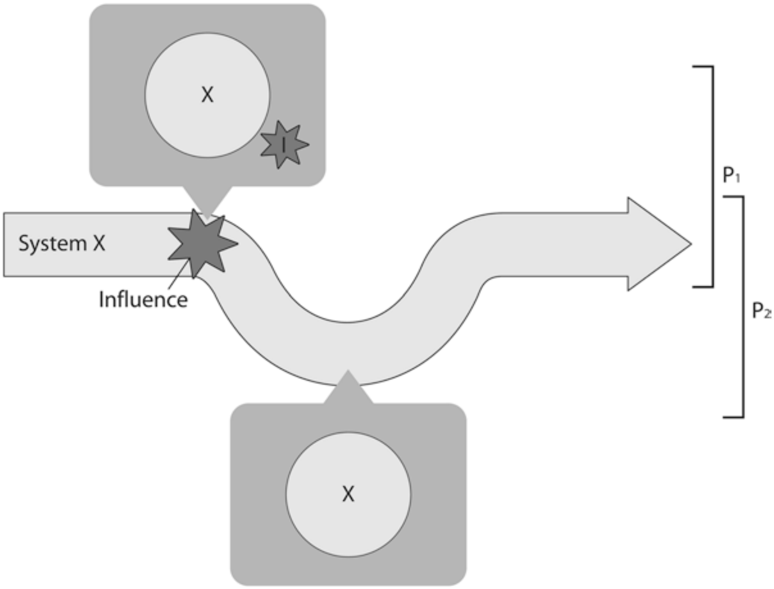


Fig. 5 Diagram showing Example 2, a system (X) that responds to an influence by temporarily fulfilling one purpose (P_2). Once the influence is no longer affecting the system, the system recovers to the initial system state

athlete's career. However, if an observer was looking at the athlete at a higher level of abstraction, over a 20-year career, then these periods of recovery may be unnoticeable, and the athlete would appear to be resisting influences.

If the system is observed at points in time before and after a recovery, the difference between robustness and recovery will not be observable. Similarly, if an observer can only see the section of time when the influence affects the system and not the recovery, then it may look like the system is adapting or flexing. Redundancy in the system can increase the speed of recovery because the core functions of the system can be performed by the redundant components (P20).

Changing to Accommodate Influences (R3)

Traditional design approaches, which focus on designing robust and performance-optimized systems, will not necessarily result in resilient systems. These robust systems are able to tackle existing and predicted influences but can become rigid and fragile if faced with new and unexpected influences. To avoid this, a system must also have the capacity to change. Example 3 shows a system that is optimized for specific functions, but this limits the possible changes that can be made in the future without breaking the whole system. Eventually when an unexpected event influences the system, the system cannot change in time and breaks down.

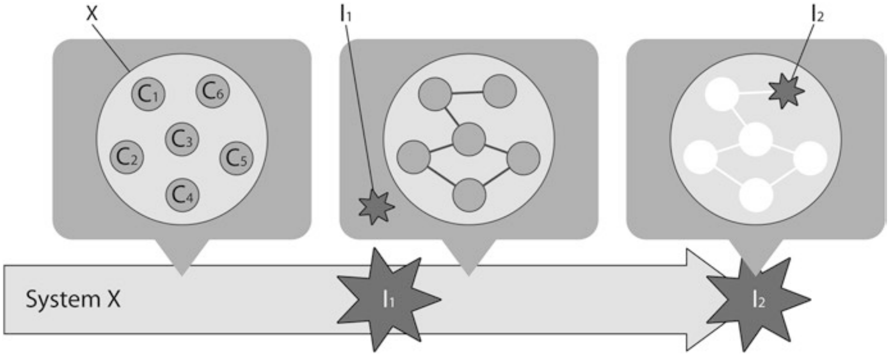


Fig. 6 Diagram of Example 3 showing a system (X) where the structure is optimized in light of the first influence (I_1) to increase the system's robustness. When the system is influenced for the second time (I_2), the structure of the system does not allow the system to change to accommodate the influence so the system fails

Example 3 System X consists of a set of components (C_1–C_6). When an influence, I_1, affects the system, the relationships between the components are constrained to make the system faster at responding to future influences of the same type. When a second influence (I_2) of a different type damages one of the system components (C_6), the system can no longer function (Fig. 6).

Example 3 in the context of engineering: Some engineering systems are continuously developed to increase robustness, but eventually they get to the point where they might fail. Engineers counter this by creating more and more ways to try and control the performance. How do you avoid encrusting the system with constraints and making it fragile (P04)?

Engineering systems often make use of newly available technologies, which can compound the problem illustrated in Example 3. The workshop participants thought that the level of technology in the system did not increase resilience; some even thought that technological advancement decreased resilience (P16, P19). New technologies are unlikely to make systems more resilient if they are complex and not well understood or highly specialized and inflexible.

A complex system is inevitably linked to other systems, and although this might make its behaviour hard to predict, it can increase the ability of the system to change (R3) by offering multiple ways to perform functions and the potential for new functions (P07). Similarly, a system that is vulnerable but resourceful can be said to be resilient, with the capacity to change to accommodate influences. This does not necessarily mean the system has an abundance of resources but that it can use what it has effectively; this was described by one participant as "frugal innovation and adaptability" (P07). The ability to change effectively requires a balance between complexity and control. Although centralized control is an effective way to monitor and maintain a system, decentralized systems allow for bottom-up changes so they can adapt more easily and quickly to influences (P10, P18, P20). These approaches contrast with the principles of "just-in-time" (P04). Just-in-time systems are well-resourced and operate comfortably under normal operational conditions. Resilient systems may be less well-resourced but are highly adaptable to unexpected influences.

How to Structure a Discussion About Resilience

Working from a systems viewpoint raises some important issues that occur when dealing with multiple stakeholders who have varying perspectives, working at different levels within a system. The workshop data showed three features of systems that must be defined to make communication easier: the system boundary, the system purpose, and the stakeholder's perspective.

System Boundary

Whether a system is considered to be resilient or not may depend on where and how the system boundary is drawn. This is illustrated with Example 4, where the resilience of a system is determined by the definition of the boundary.

Example 4 System X consists of two sub-systems (X_1 and X_2). When an influence (I) affects system X, one sub-system survives (X_1), but the other sub-system stops functioning (X_2). System X_2 is not resilient to the influence but systems X and X_1 are resilient (Fig. 7).

Example 4 in the context of biological sciences: *Staphylococcus aureus*, or SA, (system X) is a type of bacteria that is a common cause of infection, often treated

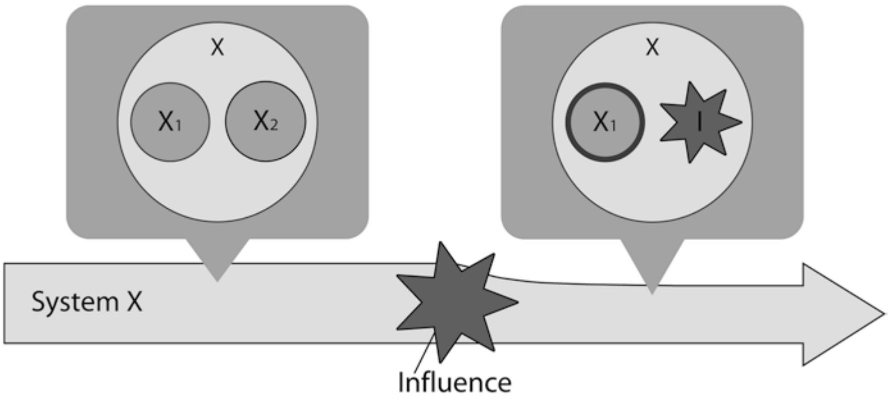


Fig. 7 Diagram of Example 4 showing the resilience of system X when affected by an influence (I)

with penicillin (I). However, over time some of these organisms have developed into methicillin-resistant *Staphylococcus aureus* (MRSA). MRSA (X_1) is not any more virulent than other SA organisms (X_2) but is resistant to antibiotics such as penicillin. Can you say that SA is resilient or only that the subset of MRSA organisms is resilient (P06)?

The participant describing Example 4 in the context of a biological system defines the system as a species of bacteria *Staphylococcus aureus*; therefore the system is resistant (R1) to the influence of antibiotics. There is, however, degradation of the system in this case; some of the bacteria, those not resistant to the antibiotics, are destroyed by the antibiotics. If the system was defined excluding the resistant strain "MRSA," then the system could not be called resilient because the whole system would be destroyed by the antibiotics.

Drawing a system boundary is not always straightforward. Sometimes it is unclear which system should be made resilient, and sometimes a system cannot be clearly defined (P19). When different stakeholders talk about the resilience of a system, the system boundaries that they each draw may be different, reflecting their individual responsibilities and perspectives. Dividing a complex sociotechnical system into component parts or events for analysis can be an overly simplistic approach as system resilience may have to be considered holistically (P18, P20).

System Purpose

Once the boundary is determined, it is important to be clear about what the purpose of the system is (these steps may not be sequential since the boundary could be defined based on the purpose that is being addressed). The purpose of the system should reflect the value that the system is delivering, the functions that the system performs, or the identity that the system maintains. Resilience can then be defined by the ability of the system to maintain that purpose (P19). The importance of defining a purpose is shown in Example 2 in the context of psychophysiology. If thepurpose of the athlete is not defined holistically, with the system boundary defined to include mental as well as physical performance, then their career could be short-lived.

Example 2 (continued) in the context of psychophysiology: The "emotional resilience of an athlete" could refer to at least two different things: the way a person (system X) maintains high levels of physical performance (P_2) despite setbacks to their mental wellbeing (P_1) or the way a person maintains high levels of mental wellbeing despite setbacks to their physical performance (the second case might be the reverse of the first case, i.e. Fig. 5 could represent both situations with the purposes, P_1 and P_2, reversed). Maintaining mental wellbeing may conflict with maintaining extreme levels of physical performance. When someone says that an athlete is resilient, do they mean resilient in terms of performance or wellbeing (P05)?

Example 2 also highlights how different stakeholders may define the boundary and purpose of the system differently. The athlete might have a personal trainer who is trying to increase their physical resilience by controlling their exercise and nutrition, whereas a psychologist might prescribe rest and social interaction to improve the athlete's emotional resilience. If the purpose of the athlete is defined as maintaining a high level of performance over a period of 6 months for a particular event, then the emotional wellbeing of the person is likely to receive less investment than their physical health. If the athlete's purpose is to maintain their performance over a period of 20 years, then it is more likely that the available resources will be distributed more evenly to achieve both physical and mental resilience.

Once the boundary and purpose of relevant systems have been identified from the perspective of different stakeholders, the cost of resilience can be considered. In the workshop, cost was not necessarily seen as monetary but what the system, or the "owner" of the system, has to give up in order to increase resilience (P03).

Level of System Abstraction

Although differences in stakeholders' perspectives can make defining resilience difficult, the usefulness of a variety of viewpoints, from multiple levels of abstraction, in sociotechnical projects was also highlighted in the workshop. An emphasis was placed on the importance of decision makers being able to understand and benefit from the perspectives of their team (P10). This would be helped by the stakeholders being able to articulate how they are defining the system boundary and purpose. Example 5 shows how viewing a system from different levels of abstraction can lead to different approaches to resilience.

Example 5 System X is affected by an influence and divides into three separate systems (X_1, X_2, and X_3). Defining the purpose of these systems is dependent on the perspective of the stakeholder. At a high enough level of abstraction, X_1, X_2, and X_3 might appear to have the same purpose, P_1, which encompasses P_2 and P_3 (Fig. 8).

Example 5 in the context of human geography: An island community was facing environmental threats in the area where they lived. Some of the people stayed in

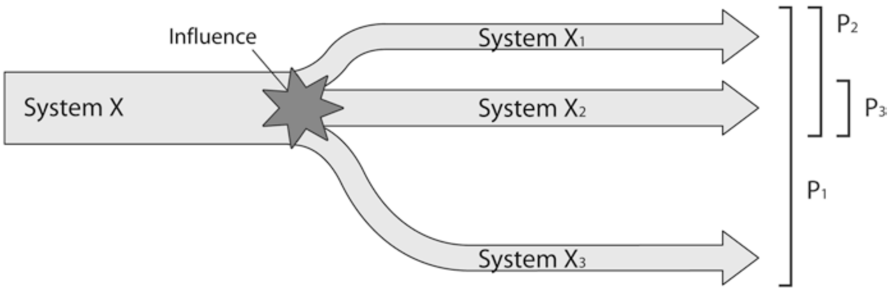


Fig. 8 Diagram showing Example 5, a system splitting into three groups fulfilling different sets of functions

the area (X_2), some moved to a new area of the island (X_1), and others left to live in a new country (X_3). These groups fulfil different purposes: living as a community (P_1), living as a community anywhere on the island (P_2), and living as a community in the original area of the island (P_3). Which group of people are most resilient (P02)?

In the human geography example above, all three groups of islanders could be considered resilient depending on the perspective of the observer. The islanders who stayed in the dangerous area considered themselves resilient, resisting and recovering from environmental forces and adapting their infrastructure (P02). Those who moved to another country did not consider themselves resilient because from the islanders' perspective, the value of their community is inherently linked to the area on the island that they came from. However, the researcher, as an outside observer, saw the group who moved away as most resilient, adapting to a new culture and thriving as an ethnic community in a new country (P02). Whether each of these different groups is resilient depends on what essential features define the group: being in a specific area, being on a specific island, or just being a community.

Stakeholders who are within the boundary of the system may not be able to abstract and look at the system from an outsider's perspective. Equally, an outside observer may not be able to understand the perspective of those acting within the system. As a result, these different people may declare the same apparent system to be or not be resilient depending on the perspective they adopt, the level of abstraction they view the system from, and the values they hold.

Summary and Conclusions

Sociotechnical systems are complex and interconnected and have emergent properties. Just as the system boundary might be hard to define, there are often "black boxes" in systems that might be measurable under normal operational conditions but still not be fully understood (P15). Current design methods often assume a reducible, controllable system, but this is usually far from the truth. In practice, systems are modelled and simulated based on assumptions, so that when a system is affected by influences that contradict those assumptions, it can behave in unexpected ways. To compound this, understanding the perspectives of other stakeholders is not trivial.

Drawing together policy makers, industry practitioners, and academics from across domains has demonstrated how many of the same issues arise in apparently disparate systems. The main barriers to understanding resilience are the ambiguity of the terminology and the lack of tools available to communicate this multifaceted concept. Three characteristics of resilience emerged from the workshop data, which are consistent with definitions of resilience in the literature: resilience as resisting influences (R1), resilience as recovering from influences (R2), and resilience as changing to accommodate influences (R3). This combination of resist, recover, and change was identified as a strong defensive design strategy for both prevention (to minimize the effects of an influence) and exploitation (to take advantage of new opportunities). A resilient sociotechnical system is likely to have components that collectively possess all three of these characteristics. However, understanding of the third aspect, related to system flexibility and adaptability, is underdeveloped both in the literature and in practice and therefore the most difficult concept to communicate.

It is necessary to look at resilience, and system changes, in the context of time. In the system lifecycle property literature, this is dealt with by showing systems responding to stimuli over time (Nachtwey, Riedel, & Mueller, 2009). Considering system behaviour over longer time periods represents new challenges compared to static analyses used in fields such as robustness engineering (Fitzgerald & Ross, 2012). The notion of time and change over time is evident in many of the system examples presented here. However, the stakeholders tended to represent systems at discrete intervals, talking about a system before and after an influence. This can be misleading. For example, a system that recovers from an influence over a period of a year may appear the same at the start and end of that year. However, in the middle of the year, that system's structure and functions could be very different.

In addition to resilience possessing different characteristics, much of the confusion that surrounds discussions of resilience can be attributed to uncertainty over three different features of systems: the system boundary, the system purpose, and the stakeholder perspective. The diagrammatic framework developed in this study encourages the definition of a system boundary and purpose, making perspectives on the system explicit. This is particularly important in identifying cross-scale interactions in sociotechnical systems, building on and extending work in the ecological and social sciences on the concept of panarchy (Allen, Angeler, Garmestani, Gunderson, & Holling, 2014). This framework also provides a foundation to explore how to communicate resilience with stakeholders who may not be as familiar with the concept as the participants of the workshop.

There are few discussions of system abstraction in the literature, although there is some representation of lifecycle properties mapped to levels of abstraction in a manufacturing system (e.g. Wiendahl et al. 2007). On the other hand, there is a strong emphasis on the importance of defining system boundaries, with the aim that system influences and responses can be shown relative to the system boundary (de Weck, Eckert, & Clarkson, 2007; Haberfellner & de Weck, 2005; McManus et al., 2007). This study confirmed that defining a system boundary is an essential step when understanding and talking about resilience (Midgley, 1992). Currently the literature focuses on resilience and changeability for a given system at a given level of abstraction. Looking across levels of abstraction leads to new insights about resilience. For example, a single technical system might appear fixed from the perspective of a stakeholder operating at a managerial level, but it might appear changeable to a technical expert.

In this research, purpose emerged as a core theme. Identifying the purpose of a system tells us about the nature and function of that system as well as the perspectives of its stakeholders. However, some systems are perceived by stakeholders as not having a "purpose"; rather they just exist. This raises an important distinction between the study reported here and the ecology literature. We have taken the stance of treating resilience as a multi faceted concept, arguing that resilience should be treated as a cross-domain concept rather than, for example, treating ecological resilience as fundamentally different to engineering resilience. However, for the most part, the social and technical systems discussed by the participants are human constructs, designed by and for people. Even in cases where these systems are autonomous and evolving, they were created with some purpose in mind. It is unclear how this work could be applied to systems without a definable purpose. This includes some large social systems and ecological systems. Although, as with much of this work, purpose is perspective dependent, there might be cases even for ecological systems where certain stakeholders can define a purpose for that system. For example, taking the city example in the quote above, a mayor might have a very clear purpose or vision for their city, so applying the systemic approach developed in this research could still be of use.

Resilience is an important concept in the specification, implementation, monitoring, and maintenance of many sociotechnical systems. However, discussions about resilience are hampered by confusion and ambiguity, especially when different stakeholders are representing different systems or different aspects of the same system. By bringing a diverse group of system stakeholders together, opportunities were explored for increasing clarity about resilience. Collecting accounts of resilience in real-world systems brings richness and tangibility to a topic that can often be vague and ill-defined. This can provide a useful basis for engaging with system stakeholders during design, offering ways to record their perspectives and ways to structure and communicate those perspectives to others.

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Towards a (Socio-ecological) Science of Settlement: Relational Dynamics as a Basis for Place

Perin Ruttonsha

Abstract Cities are increasingly garnering attention on the global political stage, in light of the challenges and opportunities urbanization engenders for transition along sustainability and resilience pathways. Recently adopted as a target for change within sustainable development agendas, and recognized as central socioeconomic vehicles by which to mobilize related initiatives, the significance of urban systems to transition becomes most evident if we conceptualize them as being integrated within broader systems of settlements. Settlements are complex adaptive socio-ecological systems, which together as globalized networks embody the complete range of human-environment interactions and the complexity that has emerged along with these, over time. This framing is inspired by science of cities research and the dwelling perspective, both of which have elaborated on cities/settlements' (1) coupled social-ecological-technological phenomena, (2) fundamental nature and function, (3) embodiment of scale-/network-based processes, and (4) emergent, multi-scale patterns of organization and impact. Ultimately, this could inform a relational approach to both sustainability and settlement planning, guided by analyses of these factors. It could also complement the burgeoning inclination in science and design disciplines to deconstruct the reflexive interactions that can occur between processes and forms, meaning and matter, people and places, the ephemeral and the concrete, the normative and the positive. By this means, we begin to invert our systemic design problem space, turning attention away from our constructed worlds, instead contemplating the ways of life they enable, in an integration between research and practice, observation and intervention, analyses and innovation, scholarship and poetics.

Introduction

Through systems and complexity thinking, so much sits between sliding doors. By this, I mean that phenomena or issues can be difficult to isolate—as we seek to work with one, we may find ourselves, inadvertently, slipping into the territory of others.

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This is the challenge of boundary definition (Cilliers, 2007; Midgley, 2000, 2003), which may complicate project planning for those who prefer to establish fixed targets for change. However, if we let our thinking gently migrate between the borders of complex issues, periodically reorienting our foci within wicked problem spaces, we may discover interconnections between phenomena of which we were not previously aware and means of combining efforts across disciplinary and sectoral initiatives. How we choose to describe (concepts/theories) and engage (methodologies) with a problem area is just as significant as the solutions we propose (applications). Creative approaches to problem solving are evermore necessary (Berkes, Colding, & Folke, 2003; Waltner-Toews, Kay, & Lister, 2008) as we make our way through what has been positioned as a critical juncture or point of climax in human history (Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015; Wilson, 2002). To traverse this passage, societies in every nation are being called to the frontline of planning for transition along sustainability[1] and resilience[2] pathways, by default of the various pressures being placed on global socio-ecological systems (Helbing, 2013; Homer-Dixon et al., 2015). This intersects with an emerging and prominent narrative that we have entered a new geological era of the Anthropocene, wherein human activity is causing impact on planetary systems at unprecedented rates and scales (Olsson, Moore, Westley, & McCarthy, 2017; Steffen, Crutzen, & McNeill, 2007).

Many of these tensions have been analysed, for example, as pertaining to biodiversity loss, climate warming, extreme poverty, and reduction in cultural diversity (Homer-Dixon et al., 2015; Steffen, Broadgate, et al., 2015; Steffen, Richardson, et al., 2015); however, recognition of these is only one step in their resolution. Related areas of inquiry and practice acknowledge that pertinent challenges for transition are often multifaceted, interconnected, wicked, complex, and inherently difficult to define or solve (Berkes et al., 2003; Curran, 2009; Gallopín & Raskin, 2002; Gibson, 2016; Loorbach & Shiroyama, 2016). They also depict the non-linear processes of systems fluctuation or transformation that are common in complex problem domains (Gunderson & Holling, 2002; Holling, 2001; Scheffer, 2009; Walker & Salt, 2006). While it is increasingly apparent that these dynamics and uncertainties circumscribe conditions for transition management[3] (Rotmans & Loorbach, 2009), we are still honing the approaches by which we can effectively act on this understanding or cope with complexity for the benefit of sustainability and

[1] *Sustainability*: This term was sanctified in the Brundtland Commission's report, *Our Common Future*, wherein sustainable development has been defined as that which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Or as Gibson (2016) has summarized, more recently, "We can begin by treating sustainability as current language for lasting wellbeing and exploring what pursuing lasting wellbeing entails" (p. 3).

[2] *Resilience*: "The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity…" (Folke et al., 2010, p. 20).

[3] *Transition*: "A transition is a radical, structural change of a societal (sub)system that is the result of a coevolution of economic, cultural, technological, ecological, and institutional developments at different scale levels" (Rotmans & Loorbach, 2009, p. 185).

resilience. With respect to cities, or human settlements, our sensibilities in this regard are maturing, as we continue to refine conceptualizations of urban systems—an effort that has found its way through diverse fields of scholarship since early civilization (Portugali, 2000). Urban and human settlement systems are slippery to characterize, as is their relevance to sustainability and resilience problem domains. There is much that could be written about the nature, form, function, and evolution of these systems, without any direct reflection on their position within and relationship to the biosphere, and not all planning theory will emphasize this aspect. However, if our goal is to achieve closer alignment between urban planning and transition agendas, developing portrayals, analyses, and plans of cities as *complex adaptive socio-ecological* systems[4] would seem to be the most logical approach (see Elmqvist et al., 2013a; McPhearson et al., 2016; Sassen, 2009; West, 2017).

Cities, on more than one occasion, have been brought into the spotlight of sustainability discourse (Bulkeley & Betsill, 2005; McCormick, Anderberg, Coenen, & Neij, 2013) and were recently adopted as an independent area of focus within the global agenda for sustainable development (United Nations, 2015b). However, there is something even more essential about human settlements (and therefore cities) to sustainability and resilience problem spaces than contemporary debates convey. Arguably, the doors between these fields of inquiry and action are sliding. While they (settlements and sustainability) may have emerged and progressed along distinct tracks (i.e. through discourses such as limits to growth and praxis such as urban planning), each with its own set of professional customs and political mandates, at their roots, they are quite close as intellectual and practical challenges. When we speak only of *applying* a sustainability (or resilience) approach *within* cities or settlements, we under-represent the parity between them, in effect, narrowing the scope of transition efforts to classic urban issues, as they are expressed within confined geographical boundaries (see Bulkeley & Betsill, 2005; Elmqvist et al., 2013b). This inadvertently frames the problem of urban transition on terms that would limit our ability to imagine transformative solutions. The coupled social, ecological, and technological dynamics of settlement systems are evident (McPhearson et al., 2016), as is their concurrent dependence and impact on the natural environment (McDonald, Marcotullio, & Güneralp, 2013); still, even these points do not quite capture their significance to sustainability (and resilience) issues. To comprehensively and accurately articulate the similarities and intersections between these fields (settlement and sustainability), we require an open position in the definition of each.

Fundamentally, both are concerned with how human populations have organized within the biosphere, over time, in an effort to survive and thrive; or, how we have

[4]*Socio-ecological Systems*: "The evolving world system can be considered a socio-ecological system, comprised of environmental and human subsystems and their interactions. The environmental subsystem, in turn, is composed of ecosystems, biophysical processes and other aspects of the natural world. The economic system includes capital, labor, other inputs, and the production processes in which they are used. The social subsystem includes consumption patterns, demographics, and culture" (Gallopín & Raskin, 2002, p. 5–6).

chosen to *dwell* within this home planet. Settlement(s) is the substantive process and outcome of this ordering, while sustainability (and resilience) is a condition of it, whereby the ways in which we inhabit the biosphere could be more or less conducive to maintaining socio-ecological systems integrity and lasting wellbeing. Human settlements (and therefore cities) are pivotal within sustainability and resilience problem spaces because they are an encapsulation of human dwelling within the biosphere. The socio-ecological systems complexities we now confront and critique, given the uncertainty of their long-term viability (Meadows, Randers, & Meadows, 2005), are primarily a product of our changing globalized patterns of dwelling (see de Vries & Goudsblom, 2002). The broadest stance we could take in our definition, then, is to argue that *settlement* and *settlements* embody(ies) the complete range of human-environment interactions, and the socio-ecological systems complexity that has emerged out of these, over time. As an intellectual premise, this is mundanely simple. Yet in practice, when operating in systems that are conventionally divided by disciplinary or sectoral categories, it is anticipated that such a description could be disruptively integrative; or, when analysing systems that are unmanageably complex, it could be refreshingly astute to orient around a straightforward idea. Effective problem framing could serve to organize interpretations of multiple layers of systems complexity, without compressing their nuances. Generally, this has been the role of science—to reveal similarities and patterns across variations on comparable phenomena. Through efforts to develop a science of cities/settlement, research-practitioners continue to search for the fundamental properties and dynamics of urban systems, whether quantitatively, qualitatively, or heuristically (Batty, 2013a; Doxiadis, 1974; Portugali, 2012a; West, 2017). Thus, urban transition can be prefaced and inspired by reconceptualizations of urban systems—ones that would entail syntheses of analyses across more than one field. At present, we struggle to reconcile the place of urbanism within visions for a sustainable future. Arguably, this alignment could emerge through examination of the deep-seated overlap between sustainability (resilience) and settlement challenges. As we continue scholarly and practical efforts to interpret the enigmatic nature of each, sustainability (resilience) and settlement(s), we may find ourselves solving problems within the territory of the other.

At the fifth *Relating Systems and Design Symposium* (RSD5), keynote speaker Humberto Maturana (2016) put forth a similar proposition: That we could distil most environmental and social justice concerns to a single question, “how do we want to live together?” His suggestion implicitly juxtaposes sustainability against settlement while opening the door for broader inquiry into the format of human life. Maturana has left the *how* unqualified: It could refer to anything from morality to community, to policy, to infrastructure, and so on. We could respond to his question with classic design initiatives, such as the development of shelter and urban places. However, it also compels interdisciplinary and transdisciplinary approaches—specifically, those which combine analyses of human ways of life with those of the systems that support them: the ephemeral and the concrete, the fill and the structure, the immaterial and the material, the intangible and the tangible, the processes and the forms, the people and the places, the normative and the positive. The latter have been the predominant points of entry into conventional design and planning projects (Ingold, 2000; West, 2017), though this is giving way, as we designers extend our scope of interest to work in the territory of user experiences, services, social innovation, and sustainability transition (e.g. Irwin, 2015; Tonkinwise, 2015). Breaking from a preoccupation with form is necessary to hone designers' involvement in the sustainability/resilience problem space. In the case of human settlements, it is not the artefacts that require reform as much as what these systems represent, how they function, and the behaviours they permit or constrain. Maturana's (2016) question is timely, as industrial civilizations evaluate the socio-ecological systems pressures, risks, and vulnerabilities we have propagated in the name of human progress. It is also profound in that it reduces multiple complex issues to a simple line of inquiry—one that could cross into territory as routine as city building and as remote as the nature of human nature. Settlements are a support system for human life, as well as a self-organizing and emergent outcome of it. By situating these two interests (settlement and human life) within the same research and development programme, we could reduce redundancy within the transition problem space and reveal insights about one through exploration of the other. In effect, we would be stripping away conceptual complexity where it does not serve us, and engaging with settlements as a tractable forum wherein which we might secure at least an operational grip on systems change, across a range of factors.

Sharing its historical development with the fine arts, those in the design field have a proclivity for the philosophical as well as the poetic; we pontificate on ways of looking at the world to guide our approaches to creating, or co-creating, within it (i.e. Alexander, 2002–2005). At the same time, design thinking and practice, to various degrees, have attempted to adopt the methodological rigour of the sciences in problem solving (Cross, 2007; Edmonson, 2007/1987; Simon, 1996/1969). Jacobs (1961) has reminded us of the need for both in city planning. A city is artful though not a work of art; it must, in her words, be illuminous of and ennobling to everyday life. This chapter engages with the dwelling perspective, as initially introduced by Heidegger (1993/1971) and later expanded by Ingold (2000), to serve as a bridge between both art and science; to connect the intellectual and practical domains of human quality of life, settlement, and transition along sustainability and resilience pathways; and to ground urban planning and design decisions in a sense of our own embeddedness within the biosphere community. Its origins (by Heidegger) are phenomenological and poetic and offer an interpretation of the meaning of building as an extension of our being in the world. Its subsequent variation (by Ingold) integrates anthropological and human ecological influences to evoke processes of building (and dwelling) that are nothing short of complex and adaptive. In describing the co-evolutionary, embodied processes by which the built environment emerges, the dwelling perspective carries tones of design, planning, sustainability, resilience, complexity, and socio-ecological systems thinking. So too does it challenge us to reconsider the intrinsic nature and underlying functions that epitomize and drive the existence and development of settlement systems. In these ways, it contains seeds that could inform an integration between science and design, research and practice, observation and intervention, analyses and innovation, and as the conceptual basis for a socio-ecological science of settlement. Some of the ideas explored within this chapter were reviewed in collaboration with the systemic design community, through two conference workshops (Ruttonsha, 2016a, b).

Cities: Sustainability

Settlements are a curious breed of human manifestation. More accurately, they are clusters of manifestations—some constructed, some emergent, some coordinated, and some self-organized—which appear together as generally cohesive systems. This is their paradox: Settlements are both planned and self-evolving systems, artefacts and dynamic systems (Batty & Marshall, 2012; Bretagnolle, Pumain, & Vacchiani-Marcuzzo, 2009; Portugali, 2016; Zamenopoulos & Alexiou, 2012). Cities have been framed as wicked, complex, inherently social, and key to sustainability transition (Castells, 2008; Pflieger, Pattaroni, Jemelin, & Kaufmann, 2008; Portugali, 2016; Rittel & Webber, 1973; Sassen, 2009). Sustainability challenges have also been described as wicked, complex, and inherently social (Curran, 2009; Gallopín & Raskin, 2002; Gibson, 2016; Rees, 2010, 2017; Wilson, 2002); additionally, international sustainable development agendas have recently granted more significance to cities as an area of focus (United Nations, 2015b).

With the Brundtland Commission's 1987 report positioning city planning as a prospective channel by which to achieve sustainable development, and the United Nations more recently incorporating a city-oriented category within the 2015 Sustainable Development Goals (SDGs), a unification of purpose between sustainability and urban planning has been underway for nearly a half century (Bulkeley & Betsill, 2005; United Nations, 2015a). However, there is a question of conceptual hierarchy to be addressed: Are settlements a practical point of entry for transition initiatives, or do they also embody something more, such as the extent to which human communities have en(dis)abled what we would deem to be sustainable ways of life, over time? Contemporary debates exploring the relationship between cities (settlements) and sustainability (resilience) recognize that urban systems are both locations and vibrant actor networks: "Cities are entities in transition themselves as much as that they are the spaces within which novelties emerge" (Loorbach & Shiroyama, 2016, p. 4). In the section that follows, I suggest this indicates the presence of two overlapping, though distinct, positions on how we could frame and work within the arena of urban transition: two positions which predicate a third. It is this third position—that settlements are complex adaptive socio-ecological systems, which embody the full range of human-environment interactions—which I argue is most central to aligning sustainability (resilience) and planning agendas. There are reasons to focus on cities (as opposed to smaller settlement systems or larger national systems) in transition planning, given how their certain qualities and impacts are magnified at scale, while being organized within ranges that are manageable for immediate and tangible interventions. So too have the implications of global urbanization trends provided impetus for review of municipal policy and planning approaches.

Much of the literature referenced in this chapter is urban-centric, though it is not intended to promote urbanized systems as a panacea for the future of sustainability. Rather, we could say that urban systems have become, of late, somewhat of an attractor for sustainability action, if only because they are seen as dominant or unwieldy. This leaves scholars and practitioners debating appropriate objectives, analytical tools, and pathways for urban transition, while also working to justify the relevance of cities to international sustainability agendas, more generally. Here, the author proposes that the significance of urbanism is understood best by examining its role within global socio-ecological networks. With the aim of contributing to a socio-ecological science of settlement, this chapter groups all settlement types, including cities, into one family, such that we might address related issues against the backdrop of what is evolving into globalized, networked systems—ones that are, notably, urbanized. The proceeding section progresses, first by discussing the general context compelling the advancement of a socio-ecological science of settlement within an urbanizing world (cities as tension) and then by outlining three positions on the relevance of cities to transition along sustainability and resilience pathways (cities as target, cities as traction, cities as embodiment). This typology is offered as an exercise in problem framing and has been derived through a reading of select discourse, coalescing recently to connect cities with international sustainability transition programmes. Each of these categories is seminal to urban transition discourse, though they will have different implications for the kinds of interventions pursued and the institutionalization or self-organization of related action. The final category reveals the closest parallels between urban and sustainability planning, and also illuminates why cities are most interesting when analysed in reference to their position within systems of settlements. If present explanations of the relationship between cities and sustainability are ambiguous, this may be indicative of another pivotal challenge for transition: To understand the connections among the numerous complex, cross-scale phenomena that characterize sustainability and resilience problem spaces.

Cities as Tension

There has been increasing international interest to place cities at the centre of sustainability transition, oriented around a general sensibility that they are the problem and solution to, or opportunity and challenge for, related concerns (UN-Habitat, n.d.; Elmqvist et al., 2013a; Ernston et al., 2010; Seto, Sánchez-Rodrígez, & Fragkias, 2010; West, 2017). More provocatively, it has been suggested that "The future of humanity and the long-term sustainability of the planet are inextricably linked to the fate of our cities" (West, 2017, p. 214) (also see Sassen, 2012). A few common arguments shape this conversation, namely, which emphasize the high percentage of world population located in urban regions (United Nations, 2015a); the stress of urbanization processes on global social and ecological systems (Elmqvist et al., 2013a); the debated links between urbanization and socioeconomic growth

(Fragkias et al., 2013); the considerable levels of resource demand and consumption, as well as carbon emissions, attributed to cities (Grimm et al., 2008; Loorbach & Shiroyama, 2016; Madlener & Sunak, 2011); the concurrent economies and diseconomies of scale enabled through urbanism (Batty, 2013b; Bettencourt, 2013a; Bloom, Canning, & Fink, 2008; McDonald et al., 2013; West, 2017); the social, political, and economic centrality of municipalities (Lane, Pumain, & van der Leeuw, 2009; Sassen, 2012); the extent to which our most prevalent issues of unsustainability take stage within urban contexts, especially as tied to the sociotechnical systems required for their operation (Florida, 2014; Loorbach & Shiroyama, 2016; Sassen, 2009; Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010); and the potential to combine urban growth planning with other sustainability initiatives (Angel, 2012). This is the basic diagnosis, and as would be expected, the issues and opportunities under discussion are cross-cutting. However, despite a wealth of enthusiasm and debate within the field, still under-defined is the scope of change warranted to arrive at a sustainable future or how closely cities of tomorrow will resemble cities of today.

Resilience, social innovation, and urban transition literature all distinguish between incremental, adaptive change and radical systems transformation (Folke et al., 2010; McCormick et al., 2013; Rotmans & Loorbach, 2009; Westley & Antadze, 2010). In resilience thinking, magnitude of change is described with reference to a shift from one regime, or basin of attraction, to another, or conversion to a fundamentally new ecological, economic, and/or social system (Folke et al., 2010; Scheffer, 2009; Walker & Salt, 2006). In a similar vein, elsewhere (Ruttonsha, 2017), I differentiate between sustainable design and design for sustainability, with the purpose of examining relationships between design, innovation, complexity, and emergence. Sustainable design engenders a conscientious approach to practice and could be incorporated in any conventional design project, from building retrofits to green space development. As designers, we can adopt a sustainability mindset (or principles) without really changing the scope or focus of our practices. By extension, design for sustainability infers the application of design-based concepts, methods, and tools to grapple with a range of complex and interconnected phenomena, in addressing systems transformation, more broadly. With *sustainable design*, we might seek to improve the energy efficiency of the built environment; with *design for sustainability*, we might restructure its organization and socioeconomic function, within the urban plan, to permit an overall reduction in energy use. Here, the concept of upstream versus downstream approaches to sustainability planning is also relevant. In downstream approaches, we might mitigate the environmental impacts of human action—with initiatives such as recycling programmes—while in upstream ones we may attempt to prevent these impacts from occurring in the first place, for example, by developing products with minimal to no packaging (see James & Lahti, 2004). Namely, it is a fancy metaphor that encourages targeting solutions at the root causes of issues. However, where social, ecological, and technological factors are significantly entangled (which would certainly be the case in cities), our view and pathway out of the systems we inhabit may be obscured. The root causes of the urban sustainability dilemma are buried within complex socio-ecological relationships.

Design for sustainability, or upstream planning, need not entirely supersede sustainable design, or downstream planning, as the latter could lead into the former. The built environment can show us how. For example, using embodied energy calculations, Mazria (2003) has estimated the built environment accounts for 48% of total energy consumption in the United States. This figure is presented in a pie chart he created as an alternative to sector-based statistics on energy use and emissions, which are typically divided into the categories of transportation, industry, residential, and commercial. In his chart, Mazria folds residential, commercial, and part of industry under the new category of “architecture,” to draw attention to the impact of built forms, building materials, and construction processes, as they are contained within these sectors. He has recommended targeting existing buildings, along with new development, as significant points of traction for energy transition. His approach to building reform is consistent with the conventions of sustainable architectural and engineering practices; however, he has also justified the work as pertinent to local and national energy policies, thus elevating it to a macro-level strategy. For Mazria, targeting the built environment in this way would represent a paradigm shift in how we analyse and manage national energy consumption, not simply a design imperative. As such, he has adapted a classic sustainable design programme with a broader view to designing for sustainability. At the same time, we should bear in mind that with every building retrofit we undertake, we recommit to the existence and placement of this form within the urban plan—a plan which will influence how we, as citizens, move through and engage with spaces of residence, leisure, and business. Designing for sustainability is a little like manoeuvring a sliding tile puzzle (or as Mazria has described, a Rubik’s Cube), wherein we must determine the appropriate sequence of interconnected moves by which to arrive at a desired, yet only partially apparent, outcome. Seeking to improve the energy efficiency of the built environment is, no doubt, essential to sustainability strategies for cities; however, our pursuit of transition along these parameters should not offset simultaneous probing into the organization and function of the built environment, more generally, and the implications of these factors on resource consumption or quality of life.

The relevance of urban spatial layout to energy consumption is most apparent through the lens of transportation planning. Thus far, work in this area has taken advantage of the complete down-to-upstream planning gradient. At the bottom of the stream, we have options to reduce the ecological footprint of automobile technology; farther along, we have diversified the portfolio of personal transit options, with bike lanes, light rail, and otherwise; finally, near the top of the stream, we have redeveloped urban plans with walkable, mixed-use neighbourhoods (Condon, 2010; Newman, Kosonen, & Kenworthy, 2016). The wisdom of this final solution, as a planning strategy, is that citizens’ path and frequency of transit through space is just as applicable to sustainability thinking as the devices employed to facilitate this movement. Walkable neighbourhoods place basic amenities and services within close proximity to residential areas, to minimize reliance on either automobiles or public transit. To augment this strategy further, we could continue to analyse the relationship between our daily routines and spatial use, over time (see Bulkeley &

Betsill, 2005). In the least, transformative change within urban contexts might entail disruption of existing urban plans, to complement or simplify the path of these flows. Some might perceive this to be a significant move.

In a design charrette, wherein participants were deliberating options for the revitalization of a European city, Architect Luigi Ferrara, Dean of the Centre for Arts, Design and Information Technology at George Brown College, said to one team, “Don’t be afraid to be radical.” In this instance, he was referring to knocking down the wall of a parking garage to make room for cultural amenities; however, his underlying point was that we should not hesitate to disrupt our own sense of certainty, with respect to the built environment, or otherwise. Though the parking garage in question exhibited relative permanence within the urban plan, it was also a relic of previous spatial-use priorities. Each of us will have personalized and socialized perceptions of what counts as radical action, or what qualifies as innovative, depending on our commitments and the current state of the systems in which we are embedded; in some instances, our characterization of the problem space informs these. One limitation of addressing urban transition through the analytical frames and praxis of urban planning and policy is that our view of whole systems may be subsumed under a categorical division among what we have defined to be our primary and functional needs—such as housing, transportation, energy, green space, public amenities, and cultural assets (see Jacobs, 1961; Mehaffy, 2008; Tomalty, 2009b). Without abandoning planning, altogether, we could use a means of ratcheting ourselves out of these boxes, to find our way to the top of the stream.

Today, urbanization is status quo and with modern industrial patterns of settlement being the dominant basin of attraction (Sassen, 2012). Thus, urbanized systems bestow much of our starting conditions for transition initiatives, whether we like it or not. The mantra that we can only ever *start from where we are at* is found in social innovation thinking (Westley, Zimmerman, & Patton, 2009). It could also be a proverb for systems transformation, more generally. Starting conditions can offer grist for innovation and present barriers to change. Currently, the lives and livelihoods of more than half the global population are reliant on the infrastructure, amenities, services, and social contracts imparted by urban systems (Loorbach & Shiroyama, 2016; Sassen, 2009). This does not dictate that urbanism as we know it must persist, that unsustainability is inherent in urbanism (McCormick et al., 2013), or that the current conditions of urban regions are the ultimate expression of urban ways of life:

> …is it urbanization *per se* that creates environmental problems, or is it the particular types of urban systems and industrial processes we have implemented? Are negative global ecological conditions the result of urban agglomeration and density, that is, the urban format? Or are they the result of the specific types of urban systems we have developed: the urban content, meaning the transportation, waste disposal, building, heating and cooling, food provision, and industrial processes through which we extract, grow, make, package, distribute, and dispose of all the foods, services, and materials we use? It is, doubtless, the latter…. (Sassen, 2012, p. 300–301)

If there is a new face of urbanism hovering somewhere in the adjacent possible[5] (from Kauffman, 2000), preoccupation with systems that have developed out of industrialization, and our efforts to render these "less bad," may elude our chance to discover it. Sustainable development has been criticized as ineffective, for similar reasons—essentially to say that we are not pushing systems far enough into a new basin or that we are locked in to perpetuating systemic unsustainability (Gibson, 2016; Loorbach & Shiroyama, 2016; McCormick et al., 2013). But what are the grounds by which we should be enabling path-breaking transformation? Here, I suggest the path to change will become apparent through deep deconstruction of socio-ecological systems, across multiple parameters, more so than efforts to envision radically different futures, or premature abandonment of our inhabited places; however, ultimately, both of the latter may occur. The reasons for the first step (this being systems analyses) are to overcome either our imagination or social behaviours reverting to familiar patterns, leading only to a remake of the past, and to ground our creative work in the logic of social and ecological systems phenomena. Notice Sassen's (2012) use of the word "content" in her quote above, and how she elaborates on what this urban content includes. Indeed, she is correct: How we have come to organize these subsystems and provide for basic services through the application of industrialized technologies, in many ways, has circumscribed the urban profile and what we would, therefore, associate with urbanism. Many of these subsystems are intrinsically indispensable, such as those which ensure appropriate food provision or waste disposal. However, also accompanying city systems are types of infrastructure and programmes which may not be intrinsic to urbanism, as much as an outcome of socio-ecological systems complexity, such as backyard swimming pools or movie theatres. Thus, determining the most suitable content for urban systems should remain an open point of inquiry. Analyses, or reinterpretations, of the systems in question, whether through qualitative or quantitative research, could disrupt convention and provide fodder for innovation.

We find methodological touchstones for this within the thinking of architect Christopher Alexander (1964), social and computer scientist Herbert Simon (1996/1969), and inventor Sakichi Toyoda. Alexander's (1964) concept of the *form-context boundary* relayed the importance of dissecting the relationships among the objects we construct and the world in which they are situated. By his estimation, at times, it may be the contexts, not the objects, which deserve review and modification (Ruttonsha, 2017). As an example, he has contrasted the exercise of redesigning a kettle against redeveloping the means by which we heat water in the home; in pursuit of the latter, it is possible the former would become obsolete. Simon's *limiting systems resources* concept suggested we probe at the key constraints we are attempting to manage for, within projects. He identified the scarce resource of human time as one such example, conceding this is equally important to assess as technological factors, when planning operational efficiencies in a business. His primary message

[5] *Adjacent Possible*: "The adjacent possible is a kind of shadow future, hovering on the edges of the present state of things, a map of all the ways in which the present can reinvent itself" (Johnson, 2010, p. 31).

was to focus on our ultimate goals, in problem solving, rather than fussing to improve the means by which we have attempted to accomplish something similar in the past. Following a comparable line of thinking, Toyoda's *five whys* method was intended to help teams evade superficial responses to problems encountered within industrial settings, through a process of sequential inquiry (Ohno, 1988). The five whys process is initiated by framing a basic question about the identified problem (i.e. why did this occur?). Then, the presumed trigger of the targeted issue is used to inspire a subsequent question (i.e. why did this trigger occur?), and so on, until finally, a root cause is isolated and a countermeasure proposed (Ohno, 1988).

If we apply the above three insights of these thinkers (Alexander, Simon, Toyoda) in urban contexts, we may find ourselves tearing our systems apart at the seams. Each of these authors has provoked us, in one way or another, to spend time considering, precisely, which problem we are addressing. In Simon's estimation, problem framing has implications for agency, in how actors mobilize around issues: "…different organizations [i.e. representations] would lead inevitably to the implementation of quite different programs, emphasizing certain goals and subordinating others…" (Simon, 1996/1969, p. 142). Of course, all three authors' methods have been described with respect to applications in semi-controlled environments; in complex systems, on the other hand, causality may be considerably more elusive to track (see Cilliers, 2007). For example, when attempting to analyse the drivers of resource usage rates within urban systems, our problem space could open into a sea of *whys* for which there may not be clear or easy countermeasures. Urban contexts are sufficiently complex that the above-listed methods could not be applied comprehensively in their planning. However, the underlying principles are still relevant and have potential to be scaled up to reconceptualize the types of issues we are solving for, or, in the words of urban theorist and activist Jane Jacobs (1961), *the kind of problem a city is.*

This influential phrase was put forth by Jacobs (1961) to capture a problem in problem solving within the context of urban planning: "Which avenues of thinking are apt to be useful and to help yield the truth depends not on how we might prefer to think about a subject, but rather on the inherent nature of the subject itself" (p. 428). In her effort to redefine the nature of urban systems, she characterized them as problems in organized complexity and advocated that analyses of urban processes and their catalysts should precede the development of urban objects, such as buildings. Around a similar point in time, Rittel and Webber (1973) classified urban planning problems as *wicked dilemmas*, in reference to their dynamic open state, and social heterogeneity. Today's *science of cities* research acknowledges Jacobs as a precursor to complexity theories of cities and Rittel and Webber as bringing a fresh perspective to urban planning (Batty, 2013a, 2014; Bettencourt, 2013b; Portugali, 2011; West, 2017). Within this niche field is a small pocket of international researchers on a mission to uncover a science that could underscore the nature of cities (their structure, properties, dynamics, growth, and evolution) as a "strategy for achieving long-term sustainability" (West, 2017, p. 215). Now, more than ever, research-practitioners studying urban contexts are realizing the challenge at hand is not only to understand cities as complex and enigmatic human enterprises, we must also do so with respect to their effect on human wellbeing and ecosystems integrity. These are obvious components of sustainable development, though, again, there are various ways by which we could define and enter the problem space. The tensions raised by urbanization are clear, including the associated increases in socio-ecological systems complexity and impacts (Elmqvist et al., 2013a; Young et al., 2006). To begin to address these, Jacobs' call to reframe the problem space is still relevant. To do so, this chapter considers the distinctions of positioning cities as targets, points of traction, or something more significant, when planning for transition along sustainability and resilience pathways. As Simon (1996/1969) intimated, each of these positions will have different implications for how we devise interventions and coordinate stakeholder action.

Cities as Targets

The persuasion of urban living has been enduring, so much so that terms to further classify this era as notably urban are appearing, such as the "Urbanocene" (West, 2017) or the "Astycene" (derived from "'astos', a dweller of an urban area") (Seto et al., 2010, p. 168). At present, we are almost a decade deep into the third major wave of global urbanization,[6] which is anticipated to bring 5 billion people, or 60% of the world population, to urban regions by 2030, and 6.5 billion people by 2050 (United Nations, 2015a, 2017). This development trajectory and its accompanying socio-ecological impacts have invigorated discussion within local, provincial, and international policy settings on how to handle the host of complex issues emerging within and on account of cities: "Rapid urbanization has brought enormous challenges, including growing numbers of slum dwellers, increased air pollution, inadequate basic services and infrastructure, and unplanned urban sprawl…" (United Nations, 2017, p. 13). Shlomo Angel (2012), an architect and planner who has been preparing for the inevitability of urban expansion, has recommended we resolve the kinks of the urbanization project while cities are still growing and therefore in flux. Certainly, many municipalities would be under sufficient pressure to accommodate for growth that the political climate is favourable to review conventional approaches to urbanism, more generally. In this respect, cities have come under speculation as objects and systems for reform.

When systems are called out as targets for change, naturally we might deliberate the challenges to overcome, solutions by which to do so and indicators of success. Of course, there are a healthy complement of ideas and technologies for urban transition already on the table, as well as tested models to emulate, many of which fall into the sphere of conventional sustainable design. For example, Angel (2012) suggested a four-part strategy to growth planning, comprised of making room for growth, balancing densities, providing for decent housing, and pre desig-

[6]The first saw the rise of ancient civilizations around 10,000 B.C.; the second began around 1800 A.D., coinciding with the industrial revolution; and the third began in 2010, at which point 50% of global populations were living in urban regions (Angel, 2012).

nating space for public works. Urban planner and designer Patrick Condon's (2010) seven-rule plan for low-carbon cities includes restoring the streetcar city; designing an interconnected street system; locating services, transit, and schools within a 5-min walk from residential areas; locating good jobs close to affordable homes; providing a diversity of housing types; creating a linked system of natural areas and parks; and investing in lighter, greener, cheaper, and smarter infrastructure (pp. 14–15). Environmental scientist Peter Newman has encouraged polycentric design, oriented around the articulation of three urban fabric types (walking, transit, and automobile), and hypothesized which kinds of urban and infrastructural design schematics would be suitable for each one (Newman et al., 2016; Newman, Beatley, & Boyer, 2009). Other proposed options include everything from green to smart technologies; net-zero development; mixed-use development; diversification of energy, transit, and food systems; enhancement of ecosystem services, for example, to mitigate heat island effect and water runoff; decentralized production; circular production; resource sharing; microlending and community currencies; relocalization; social inclusion and community placemaking; and enrichment of livelihoods (Beatley & Newman, 2013; Curran & Tomalty, 2003; Hopkins, 2011; McPhearson et al., 2016; Newman et al., 2009; Thackara, 2015; Tomalty, 2009a, 2009b). At the same time, specific measures of sustainable urban development are debated, as are interpretations of urban sustainability (Tanguay et al., 2010; Tomalty, 2009b). Thus, in pursuing strategies for urban transition, we might exercise caution not to over-objectify cities as things to which we apply sustainability thinking, for example, through continued monitoring and mitigation of their performance on predesignated factors:

> While this is no doubt important, as Whitehead (2003) suggests, 'such work has tended to reduce the analysis of sustainable urban development to a technical matter of institutional restructuring, traffic management, architectural design and the development of green technologies'. (Bulkeley & Betsill, 2005, p. 43)

Targets for change provide a clear scope of action, around which different institutions and stakeholders could organize and advocate. They could also stimulate creative problem solving and innovation, where groups collaboratively brainstorm approaches for meeting stated objectives, as has been the case with local responses to climate change (climateactionwr.ca). However, targets also presume we know something about the systems in which we are operating, such as their constituent parts, how these parts relate, and how we want them to perform, cohesively. We have already started to encounter this tension in attempting to situate an urban agenda within sustainable development. The incorporation of an individual category for cities (Goal 11)[7] within the United Nations' (UN) recent list of Sustainable Development Goals (SDGs) is a notable addition from its previous eight Millennium Development Goals (MDGs), affording municipalities increased prominence on the international stage of sustainability planning. Each of the SDGs includes targets for

[7] *Goal 11, Sustainable Cities and Communities*: "Make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2015b, p. 14).

change and indicators of progress, and Goal 11 has its own set. However, the UN has also acknowledged that approximately one third of the other goals will link directly with or could be implemented through cities and settlements:

> …cities are a string that connects all other goals together; their density and economies of agglomeration link economy, energy, environment, science, technology and social and economic outputs. (UN-Habitat, n.d.)

The SDGs position sustainable cities as one goal among seventeen, though we could debate the extent to which it also encompasses the others. This is a challenge of relational organization, more so than goal setting or boundary definition—how one set of factors might influence another. For example, ecosystems and resilience thinking use the concepts of holarchy (Waltner-Toews et al., 2008) and panarchy (Gunderson & Holling, 2002) to describe hierarchical, nested, and/or cascading relationships among interlinked systems phenomena within complex systems (Cumming & Norberg, 2008). The list of SDGs assumes uniform significance among the seventeen goals, though some possible interdependencies have been identified, elsewhere (Biron, 2016; Rockström & Sukhdev, 2016). With respect to Goal 11, especially, there are questions of relational order with which to wrestle: Are sustainable cities an end in themselves, a means to attaining the other goals, and/or an outcome of successful sustainable development?

Cities as Traction

Some who hail the significance of cities to sustainability also stress that municipal governments are in a prime position to respond to related challenges, on the ground (UN-Habitat, n.d.; Biron, 2016; Bulkeley & Betsill, 2005; Loorbach & Shiroyama, 2016; Quitzau, Jensen, Elle, & Hoffman, 2013; Sassen, 2009). Given the dense clustering of people, resources, expertise, power, and innovative capacity, cities can serve as points of traction by which to mobilize global agendas (Sassen, 2009, 2012; van der Leeuw, Lane, & Read, 2009; Wittmayer & Loorbach, 2016); informal connections across diverse interest groups would enhance this effect (see Granovetter, 1973). As much as cities are places, they are also complex social enterprises (Seto et al., 2010):

> The rise of cities is not simply the growth of large collections of people—rather, it involves communities that are far more diverse than their predecessors and more interdependent. (Elmqvist, Redman, Barthel, & Costanza, 2013, p. 16)

Historically, part of the draw of urbanization has been the economies of scale, increasing returns and shared prosperity achieved through networking (Angel, 2012; Bloom et al., 2008; Pierson, 2004; van der Leeuw et al., 2009). In a comparable way, cities could put their social capital to work to tackle the challenges of the Anthropocene. When we set goals to reform urban infrastructure, programmes, and policies, as a focus for transition, we naturally enlist institutions and communities as the champions and vehicles of this action. As such, the first position, *cities as* *targets*, stimulates the second, *cities as traction*. At the same time, this second category can remind us to examine the conditions and parameters of social organization, more specifically, and the extent to which these permit or limit the pursuit of sustainability.

Urban scientist Luis Bettencourt's (2013b) classification of cities as *social reactors* or *integrated social networks imbedded in space and time* encapsulates this. His colleague, physicist Geoffrey West, has presented a similar framing: "... cities are emergent complex adaptive social network systems resulting from the continuous interactions among their inhabitants, enhanced and facilitated by the feedback mechanisms provided by urban life" (2017, p. 253). These definitions were formed as part of a newer variation on the science of cities, initiated at the Santa Fe Institute at the turn of this century (West, 2017). Of course, a comparable premise underscores Jacobs' (1961) writing, for example, with her claims to the relevance of social interaction to urban vitality—the idea being that cities are places wherein people come together to connect, support, share, and learn, and in doing so, manifest unexpected, novel realities, possibly along with resilient communities. These descriptions of urban systems imply and justify the logic of diversified participation in processes of transition. Viewed as social reactors or networks, realistically, transformation within settlement systems could only be a phased, iterative, engaged social process, wherein we build capacity and nurture tolerance for change among numerous systems actors, whether this is managed or self-organized. These such processes could be employed to propose, review, and implement the kinds of conventional sustainable design initiatives listed earlier. Additionally, as we move from sustainable design to design for sustainability, we have witnessed the design space becoming more permeable to fluid agency—precedents for which can be found in systemic design, social innovation, urban planning, and transition management (charretteinstitute.org; James & Lahti, 2004; Jones, 2018; Mehaffy, 2008; Nevens, Frantzeskaki, Gorissen, & Loorbach, 2013; Newman & Jennings, 2008; Westley & McGowan, 2014). Process design is one mechanism by which we can organize within and among social networks, in order to facilitate transition. These methods are becoming increasingly popular, in design and other forums, though related methods continue to be evaluated and refined (Jones, 2018; Reed et al., 2018).

> In the past decade, however, the conviction has grown that the traditional way of planning has to be changed to a more 'process' route, exploring the communicative dimensions of collectively debating and deciding on matters of collective concern. (Rotmans, van Asselt, & Vellinga, 2000, p. 267)

Conventionally referred to as design charrettes and developed as a tool for stakeholder consultation, programmes for participatory engagement have since expanded into think tank and co-creation models and are on the threshold of reaching higher ground, both creatively and politically. These processes can be applied to share expertise and experiences, examine the values of diverse audiences, establish common agendas for change, and formulate multi-partner initiatives, all within an extended peer community.[8] As an exercise in innovation, social learning, and democratic engagement, they are carving out new formats for decision making, and doing so within problem spaces that may have weak conceptual clarity, no obvious institutional or disciplinary home, and few clear-cut resolutions. The issues with which they are grappling are even starting to reflect post-normal science conditions[9] or points of critical transition[10] within local sites and institutional agendas. Additionally, project development can be reflexive: As we plan to apply sustainability principles within the built environment, the social settings in which we would realize prospective initiatives also come under review (Ruttonsha, 2017). If these conditions prove to be unfavourable to innovation and change, we may turn our attention from engineering infrastructures, instead, towards modifying the contexts in which we are acting:

> From these small and often simple beginnings, with all their practical objectives of improving housing, health and education, emerges an agenda of reforms to policy, legal frameworks and standards which help to build social capital, promote social integration and gender equality, reduce dependency, unlock resources and build livelihoods. (Hamdi, 2004)

As designers and innovators, we are no longer puzzle solving, in the classic Kuhnian (Kuhn, 1996/1962) sense, by responding to routine briefs for community centres, hospitals, schools, parks, or public squares. Rather, projects are becoming forums through which we collaboratively explore broader socio-ecological tensions and mandates, such as the redefinition of urban culture in a digital era; the reestablishment of a culture of nature in urban regions; the integration of vulnerable populations into urban life; the redevelopment of nations following conflict; and the enhancement of local indigenous communities' resilience to globalization (this list is based on actual cases). In the author's own experience, these opportunities can surface when existing protocols become unviable or are considered insufficient or when significant change in circumstance prompts redefinition within a system.

Cities may be in an ideal position to mobilize change, given the centralization of agency and assets; however, this does not guarantee their existing social, economic, and political institutions will be conducive to enabling *effective* change or the kind we require. Aligning actors to contribute to transition initiatives may entail strange transdisciplinary gymnastics between the articulation of options and the logistics of their implementation—especially, where the proposed alternatives cut across sectoral or institutional mandates. Envisioning transition initiatives that transcend dis-

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[8] *Extended Peer Communities* "[consist] not merely of persons with some form or other of institutional accreditation [such as scientists, industry or government], but rather of all those with a desire to participate in the resolution of the issue" (Funtowicz & Ravetz, 2003, p. 7).

[9] *Post-Normal Science* decision-making conditions combine high uncertainty with high stakes, sit at the intersection of policy and science, require evaluation of both fact and value statements, and are often embedded within complex scenarios (Funtowicz & Ravetz, 2003; Ravetz, 2007).

[10] *Critical Transitions* occur when a system shifts from one state (i.e. basin of attraction) to another (also referred to as crossing a threshold) and without prospect of returning easily to its previous state (Scheffer, 2009; Walker & Salt, 2006).

ciplinary segregation comes with the additional task of proposing the social, economic, and political models by which we would undertake these projects. For example, we could examine the constraints by which actors are bound, redefine the rules of interaction (see Helbing, 2013) between project collaborators, or consider how stakeholders might share investment, accountability, risk, and reward in the implementation of cross-sectoral, multi-scale programmes (see Wittmayer & Loorbach, 2016). Is this not the impetus behind processes of settlement, anyway: To increase our capacity to problem-solve and survive through social organization?

> It is all too often forgotten that the whole point of a city is to bring people together, to facilitate interaction, and thereby to create ideas and wealth, to enhance innovative thinking and encourage entrepreneurship and cultural activity by taking advantage of the extraordinary opportunities that the diversity of a great city offers. (West, 2017, p. 252)

From this perspective, however, we can imagine how societies could undertake endogenous modification to existing urban systems, without explicitly demanding thoughtful reflection on the patterns of socio-ecological organization they enable. One limitation of the design charrette or change lab model is that pathways of innovation may continue from previous pathways of innovation. Where innovation is cumulative (see Arthur, 2009) and path dependent—with cogenerative processes being ones through which we disseminate, deliberate, and connect the most salient ideas—we may never disrupt the worldviews from which they were inspired. Still, on the back of this, there may be potential for the self-redefinition of industrial urban societies. Reflexive modernization theory evokes this kind of process. Reflexive modernization is a sociological proposition, which has observed a contemporary involution in modern societies (Beck, Bonss, & Lau, 2003; Beck, Giddens, & Lash, 1994). Its core premise is that the Western modern world has generated sets of dynamics that can no longer be sustained by the fundamental social principles and institutions on which it was initially founded. In reaction to the destabilization of these structures, rather than abandon modernism altogether, societies are leaning more deeply into the tools, resources, programmes, and formats of the modern world (capitalism, globalism, labour, state) to reinvent what we know of it; at the same time, they are undergoing metalevel conceptual shifts in delineating modernity, as well as the rules of the game by which change occurs, which are now unequivocally non-linear (Beck et al., 2003). Reflexive modernization is portrayed as a process of creative destruction occurring within systems of social organization (Beck et al., 2003). In urban systems, we are also at a point of breaking and redefinition, whereby the rules of the game are being reassessed through growth management agendas. Certainly, the conditions of urban systems are pushing us to the edge of our own tolerance, across a number of categories, such as traffic congestion, pollution, loss of habitat and agricultural lands, decline of rural communities, social alienation, underemployment, and increased cost of living. In this light, we could look to industrialized cities as places in custody of the infrastructural and institutional facility to implement transition initiatives while simultaneously rejecting the particular schematics and social conditions endowed by modern industry: Ostensibly, we could attempt to exist within our densely constructed bubbles while also reform-ing them, endogenously. The impracticality of endeavouring this in isolated sectoral pockets continues to spawn collaborative social action. The question is whether this amalgamation of social energy can also summon the next wave of remodernization, within urban systems.

Realistically, the primary responsibility of municipal governments is to keep their ships flying; significant course correction would call for inquiry and action beyond their standard operations. Even within participatory design processes, we may not have time and incentive to engage with deeper issues, at least not with any degree of academic rigour. Neither are the most complex layers of the problem space easily accessible for intentional intervention (see Meadows, 1999). Some of these complexities include coupled interactions between nature and culture. If we contemplate the details of these interactions, we will arrive at an expanded explanation of why cities are well positioned as points of traction for transition: Namely, they are representative of how human life has organized within the biosphere, over time, and the socio-ecological systems complexity that has emerged or declined along the way (Bettencourt, 2013b; Christian, 2004; van der Leeuw et al., 2009; Tainter, 2008).

Cities as Embodiment

As a methodology, co-creation infers collaborative thought and action taking place among systems actors, to some desired effect, whether this be social learning or project development (Berkes et al., 2003). In design practice, the popularity of this approach (as described earlier) speaks to the loss of faith in the isolated, creative genius to innovate effectively within complex scenarios (see Mau, Leonard, & The Institute without Boundaries, 2004; Mehaffy, 2008). From a complex adaptive systems perspective, the term carries additional significance, with respect to the self-organizing or emergent outcomes that can arise through the cumulative actions of many. In these cases, co-creation is more like co-evolution, whereby reflexive interactions may occur between people and the systems of which they are a part (see Rotmans & Loorbach, 2009). Once we accept cities as points of traction for transition, given their dense social networks, we begin to encroach upon a further conception of these systems, wherein society could be described as the generative mechanism of urbanism or cities as an embodiment of social processes (Allen, 2012; Castells, 2008; Harvey, 1985; Portugali, 2000, 2012a; Sassen, 2010; West, 2017). In other words, not only are cities socially dynamic and diverse but also an outcome of the varied thoughts and actions of their social agents; neither are they bounded spaces, rather sites or nodes for the unfolding, or instantiation of these dynamics (Sassen, 2010). This framing reveals why the first two positions—*cities as targets* and *cities as traction*—are incomplete as approaches when identifying opportunities for transformative systems change. If urban systems are produced and reproduced through a combination of intentional, self-organized, and emergent social processes, occurring at both local and global scales, then the study of these processes is key for urban transition.

> Cities are socially determined in their forms and in their processes. Some of their determinants are structural, linked to deep trends of social evolution that transcend geographic or social singularity. Others are historically and culturally specific. And all are played out, and twisted, by social actors that impose their interests and their values… . (Castells, 2006/1993, p. 135)

Embodiment, as a concept, implies reflexive interconnection between structures and processes. For example, cognitive science proposes a model of the embodied mind, wherein our bodily perceptions, existence, and experiences shape our thoughts and reasoning (Maturana & Varela, 1980; Varela, Thompson, & Rosch, 2016); Capra (2002) has used the concept in reference to the expression of ephemeral, dynamic phenomena within physical/material form. Thus, with embodiment, the direction of influence between agents and environments can travel either way: Environments shape the behaviours of agents, and agent actions are imprinted in environments. In short, each is seen to affect the other, which, of course, is what denotes a reflexive interaction, per complexity thinking (see Jervis, 1997). For design practice, the implication is that our relationships with the contexts in which we are situated will inherently guide our ideas and creations:

> …envisioning is itself an activity carried on by real people in a real-world environment, rather than by a disembodied intellect moving in a subjective space in which are represented the problems it seeks to solve. (Ingold, 2000, p. 186)

In sustainability and resilience thinking, some contend that cultivating a tacit or embodied engagement with the natural world will enhance our reverence for it (Cooke, West, & Boonstra, 2016). Moreover, ideas about embodiment can enrich how we understand urban systems. In effect, cities are complex adaptive systems, which can emerge by virtue of the interactions among their social agents within social networks, who are also *situated within environments*. This notion has been discussed by Jacobs (1961) and science of cities scholars (Batty, 2013a; Bettencourt, 2013b; West, 2017), as noted earlier: "…cities are an emergent self-organizing phenomenon that has resulted from the interaction and communication between human beings exchanging energy, resources and information" (West, 2017, p. 280). However, where these authors have focused on urban social dynamics and network organization, as they appear in space over time, to solidify the relevance of cities to sustainability and resilience challenges, we could benefit from another layer of urban theory that explicitly directs attention to the human presence within and reliance on the biophysical environment. Embodiment implies that we are one with the environments we inhabit, not separate. In an effort to reconnect development to the natural world, and balance against social-technological analyses of urban complexity, resilience scholars are expanding conceptualizations of cities as complex adaptive socio-ecological systems while indicating the pivotal role they play in organizing human life within the biosphere (Elmqvist et al., 2013a, 2013b; McPhearson et al., 2016).

> It is in cities and vast urban agglomerations that humankind is increasingly present on the planet and through cities that people mediate their relation to the various stocks and flows of environmental capital. (Sassen, 2012, p. 299)

This chapter has initiated this discussion with reference to cities, specifically, as many related debates are oriented around urban systems. As central nodes for production and consumption (Fragkias et al., 2013; Grimm et al., 2008), social hot spots or climax areas, cities have garnered a fair amount of attention, both positive and negative. It is not the intention of this chapter to argue an urban-idealist (i.e. accepting cities as beneficial for their own sake) approach to transition, nor to write off urban systems as inherently unsustainable. Rather, it serves as a preface to ultimately explore how various patterns of and prospects for settlement could enable or disable long-term sustainability and resilience. Naturally, cities would be included within this bigger picture. In this regard, they come into view as part of broader *systems of cities* or *systems of settlements*, wherein analyses of the impact of any given city become most salient with reference to its regional and global connections (Sassen, 2012; Seto et al., 2012). In other words, more significant to our understanding of the relationship between urbanism and transition than the study of cities as designed artefacts are analyses of systems of settlements as sets of dynamic, overlapping, and intersecting networks (see Batty, 2013a; Castells, 2010a). Even the earliest urban systems emerged as interconnected regional networks (Bretagnolle et al., 2009; de Vries & Goudsblom, 2002), and contemporary rural regions are certainly committed to patterns of industrial urbanization (Sassen, 2012). The importance of thinking about settlements in this way is to unravel their tracks of influence across globalized networks and to understand how complexity manifests at scale. Building on Jacobs' (1961) description of cities as problems in organized complexity, we could continue and deepen her argument with the proposition that systems of settlements represent the organization of socio-ecological systems complexity.

Following from Sassen's quote above, we could debate the extent to which it is possible to detach human presence on the planet, or the flows of environmental capital as enabled through human action, from the constructs of settlement. After all, if we log a forest or drill an oil field, are we ever doing so without targeting these resources for use within some settlement context, such as a market economy? And, is it not the demands, constraints, and structural properties of these contexts that determine how and why these resources are consumed? Sassen's (2012) words, thus, intimate why socio-ecological or human-environment interactions are inevitably linked to some form of settlement, not only centralized within or constituent of them. This leads to the most open position we could possibly adopt in defining human systems of settlements: That together, they encapsulate all of the processes and means by which human populations have inhabited the biosphere. Whether the format of habitation is mobile or fixed is not critical for this classification;[11] the

[11] In urbanized, globalized contexts, we have even redefined the meaning of a nomadic lifestyle. Today, we can live a life on the road, supported by transnational banking, international transit, digital communication, and otherwise.

notion of being settled, rather, denotes a rootedness within the biosphere as a whole, as opposed to a specific location, therein. Sustainability as a multidisciplinary and interdisciplinary praxis entails reflecting on and managing relationships between social and ecological systems (Gibson, 2016; Hawken, 2004a, 2004b). Arguably, it is settlement systems that embody these socio-ecological or human-environment interactions (see Batty & Marshall, 2012; Wilkinson, 2011); and, it is our efforts to cope with daily living therein, from which systems complexity has developed.

> Among many, the increase in social complexity occurred in response to the need and wish to bring forth food, water and shelter from an exacting and unpredictable natural environment. (de Vries & Goudsblom, 2002, p. 149)

If we view settlement(s) as an encapsulation of the organization of human life within the biosphere, as this has changed over time, then it becomes a problem of everything—no longer just about infrastructure, or social programmes, or tax incentives. Of course, human populations have undertaken the imperative of settlement within very different historical and geographical contexts and in the face of variant pressures (Christian, 2004; Diamond, 2005a, 2005b; Tainter, 2008). By framing the challenge as one that is common to all human communities, we can subsequently discuss how different groups have solved similar problems through a range of means; the conditions and constraints that predicated their choices; what has been lost or gained along the way; and the implications of these approaches for long-term sustainability and resilience. Since the transition of human communities from nomadic to stationary patterns of living, global population has increased, along with total energy consumption, by 1400 and 60,000 times, respectively (Christian, 2004), presenting two of the most significant hurdles for us to confront in managing for sustainability, today. At the same time, some planners hint at a transcendent quality of cities, whereby we can somehow escape the worst and uncover the best of our human tendencies through these systems of human development. After all, if we position *cities as embodiment*, are we not then distinguishing them as an extension of self and society? Patrick Geddes, for example, believed the urban and the social could develop concurrently, through town planning, with opportunity for improvement in both domains (Hysler-Rubin, 2011).

The mid-twentieth-century ekistic (the science of human settlements)[12] movement—championed by Constantinos Doxiadis (urban planner and architect) and Jaqueline Tyrwhitt (town planner)—followed from Geddes' inspiration, alluding to relationships between human evolution, human development, human action, and the emergence of settlements. This design-based programme to fortify planning with science reflected a *cities as embodiment* worldview:

> …human settlements have always been created by man's moving in space and defining the boundaries of his territorial interest. (Doxiadis, 1970, p. 3)

[12]"*Ekistics* denotes both a specific settlement orientation and at the same time a wide field of interest, encompassing all those processes which have served to form settlements throughout history" (Bell & Tyrwhitt, 1972, p. 28).

Without unequivocally embracing a process-oriented view of planning, Doxiadis (1970) introduced five principles[13] by which he contended settlement systems have manifested. His principles lean towards outlining a standard set of human-environment interactions, of which settlements are an embodiment (he has also referred to them as the physical expression of man's system of life). With this list, he strived to extract common mechanisms (i.e. processes) that underlie settlement and settlements, regardless of their size or type—nomadic or stationary, urban or rural, city or hamlet. In ekistic literature, settlements of all kinds (hamlets, villages, towns, and cities) are grouped under the same family. Their relationship to one another within a system of settlements is delineated within a logarithmically scaled ekistic grid (inspired by central place theory), which starts with the smallest unit of settlement—the individual human, or Anthropos—and ends with the largest, the earth-encompassing/universal city, or the Ecumenopolis, with its transcontinental systems flows (Bell & Tyrwhitt, 1972; Doxiadis, 1969, 1974). Together, these units govern the total urban system. Given that the individual is represented as the first ekistic unit in the grid, ekistic heuristics leave little within the human realm that could be excluded from human systems of settlements—especially if we presume their embodied connection with our cognitive and emotional worlds. By studying individual settlements with respect to their position within a system of settlements, the ekistic grid inferred the importance of scale and network analyses to planning. Through its collection of heuristics, ekistics aimed to forward a globally unified means by which to interpret settlement processes, contents, and forms, highlighting similarities among all human settlements, despite variation in their size, type, or geographical location. In this way, the movement was comparable to today's science of cities in its intentions, though it had yet to benefit from the detail and rigour of more recent quantitative work.

Today, it is recognized that cities secure resources from and have impact on areas beyond their immediate geographical boundaries (Elmqvist et al., 2013b; Grimm et al., 2008; Homer-Dixon, 2006; Kennedy, Cuddihy, & Engel-Yan, 2007; McPhearson et al., 2016; Seto et al., 2012; van der Leeuw et al., 2009); that they bleed together as metropolitan regions (Castells, 2010a); and that systems of cities[14] connect internationally through "relations of exchange, trade, migration, or others

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[13]*Five Principles of Settlement*: (1) maximization of man's potential contacts with the elements of nature, with people, and with the works of man; (2) minimization of the effort required for the achievement of man's actual and potential contacts; (3) optimization of man's protective space, which means the selection of such a distance from other persons, animals, or objects that he can keep his contacts with them without any kind of sensory or psychological discomfort; (4) optimization of the quality of man's relationship with his environment, which consists of nature, society, shells, and networks; and (5) optimization of the four other principles, dependent on time and space, actual conditions, and man's ability to create a synthesis (Doxiadis, 1970, pp. 2–3).

[14]*Systems of Cities*: "What we call systems of cities are evolutionary objects that may include subsets of cities connected by long-distance networks or cities belonging to unified political territories…The precise identification of systems of cities is very difficult, due to the changing nature of the interactions that need to be considered, and the fluctuations in their spatial extension" (Bretagnolle et al., 2009, p. 200).

that sustain the flow of energy, matter and information…" (Ernston et al., 2010, p. 533; Bretagnolle et al., 2009), wherein there may exist some functional/economic differentiation among the units within each cluster (Abdel-Rahman & Anas, 2003, Castells, 2010a). Presumably, global settlement networks are self-reinforcing in their patterns. For example, some systems conditions would only be possible at a local scale given international interconnections, or perhaps also the establishment of what Sassen (2012) has referred to as a network of global cities.[15] At the same time, globalized systems of resource extraction, production, distribution, and consumption, would be entrenched *because* individual cities amass dense, captive audiences who support these processes (McDonald et al., 2013; Sassen, 2009; Young et al., 2006). In their work on teleconnections, Seto et al. (2012) have studied the effects of urban processes on land changes in distant and non-urban places. Settlements embody phenomena that occur across nested, global scales, as do sustainability challenges (Gibson, 2016; Sassen, 2010). Given the international, interconnected profile of these *systems of settlements*, we could argue that they constitute what McNeill and McNeill (2003) have described as the global human web, wherein there is potential to capitalize on their network effects to enable change (McCormick et al., 2013; Sassen, 2009). This raises questions of where to locate innovation initiatives. Are we targeting global settlement patterns as a common area of concern and/or focusing on specified local issues? From the perspective of sustainability and resilience assessment, a comprehensive view of interactions occurring across and between regions and nations would be prudent:

> Therefore, individual cities cannot be considered 'sustainable' without acknowledging and accounting for their teleconnections—in other words, the long-distance dependence and impact on ecosystems resources and populations in other regions around the world. (Elmqvist et al., 2013b, p. 735)

Settlements as Dwelling

The concept of embodiment is important both for planning and sustainability (resilience), in that it intimates the existence of coupled, or co-evolutionary, relationships between people and their environments. At the same time, it could ground urban theory and practice in sustainability and resilience interests, if applied to portray processes of settlement as analogous to human-environment or socio-ecological interactions and settlement systems as the materialization of these dynamics. Thus, the final category, *cities as embodiment*, elaborated above, is the one that draws the closest parallels between settlement and sustainability (resilience) and, arguably, is essential for transformative systems innovation within urban contexts. The first category (cities as target) recognizes efforts to adapt existing systems, in accordance

[15] *Global Cities*: This concept refers to a type of function, situated within complex cities, involving the production of advanced intermediary services (i.e. finance, legal, trade, etc.), that facilitate cross-border exchanges and globalized activities (Sassen, 2012).

with sustainability principles, for example, with energy retrofitting, diversified transportation alternatives, or affordable housing projects. The second (cities as traction) acknowledges efforts to enlist the capacities of municipal and local community networks to mobilize change, which are exemplified through design charrette and change lab methodologies. The third category (cities as embodiment) could incorporate the same kinds of technological, programmatic, and political initiatives, though it also transcends and defies intentional project planning. This category could lead to considerations of the metabolism of settlements, as complex adaptive socio-ecological systems; more so, it probes us to deconstruct how this metabolism might be tied to human thought, preference, behaviour, and action. It also positions settlement systems as integral to the human story—our history of experimentation, innovation, striving, and failure, though different in each region. This categorical progression, then, delivers us to the point of understanding the bearing of another concept—one that follows a comparable intellectual trajectory and shows clear thematic association with planning and resilience thinking. The *dwelling perspective* was coined by British anthropologist Tim Ingold (2000, 2005), though it was initially introduced by German philosopher Martin Heidegger (1993/1971, 2001/1971), and coaxes us towards a relational interpretation of the built environment and human settlement. The implications of this concept become most apparent when we accept the limitations of working with settlements as spatially bounded, constructed artefacts or as ecologically disembedded social networks. Rather, if we concede they emerge from humans interacting with each other and their environments, as part of routines of living, the notion of *settlement as dwelling* follows naturally.

Like *settlement*, the term *dwelling* could be construed to be a verb or a noun, though for these purposes the distinction is almost incidental—*dwellings*, as objects, emerge as an outcome of *dwelling*, as sets of actions, just as *settlements* appear through processes of *settlement*. The same would be the case for sustainable development, in that it can refer to an outcome or a process (Gibson, 2016). While *dwellings*, as objects, could be viewed as prospective sites for transition applications, such as building retrofits, it is also crucial to consider how *dwelling*, as a suite of processes, could be coordinated in ways that, to varying degrees, pay respect to biosphere integrity, social equality, the needs of future generations, and so on. True, we could design settlement forms with these same objectives in mind, limiting our socio-ecological systems analyses to factors that intersect directly with our intentional constructions. However, in doing so, we risk confounding means with ends. Sustainability criteria frameworks set worthy end goals, with respect to maintaining human life and wellbeing over the long term, in conjunction with socio-ecological systems integrity (see Gibson, 2006, 2016). Settlement systems are the means by which we could achieve this (rather than ends in themselves), and presumably, these means could vary widely. Also, as was discussed in the previous section, any boundary between settlement and non-settlement is vague, especially if we apply the concepts of embodiment (per Capra, 2002) or embodied cognition (per Maturana & Varela, 1980).

Wording can be crucial in problem framing, with its intimations potentially shifting perspectives. Dwelling, as a term, is more open and generic than settlement. While the latter has already been incorporated into international policy frameworks, with clear ties to sustainable development, the former, arguably, has fewer associations of this kind, thus offering some conceptual liberty. Here, I extend the commonly presumed significance of the term by relating it to globalized, networked phenomena. Heidegger's (1993/1971, 2001/1971) original treatises on dwelling were etymological and poetic. On the premise that language is seminal to discovering the nature of a thing, and poetry a revelation of truth (Heidegger, 2001/1971; Hofstadter, 2001), he unpacked the essence of dwelling through deconstruction of its linguistic roots (from the Old High German word for building, *buan)* as well as an eighteenth-century German poem by Hölderlin (*In Lieblicher Blaue*/*In Lovely Blue*). With this, he resurrected former connotations of the term dwelling (to stay, to cherish and protect, to preserve and care for, to cultivate the vine) and bestowed built form with enhanced meaning. To follow his method, we could contemplate the close association between the two words, *settlement* and *dwelling*, to interpret artefacts like cities as a means by which humans inhabit the earth. The dwelling perspective, in its various iterations, has carried direct and indirect tones of design, planning, systems, complexity, sustainability, resilience, and socio-ecological systems thinking and is becoming evermore versatile as it matures. Heidegger's initial depiction sought to capture a wholeness in the relationship between mortals and their inhabited environments, though with a spin that was more metaphysical than ecological. Others who have extended his thinking (Cooke et al., 2016; Ingold, 2000, 2005) have fortified the ecological, complexity, and human-environment angles. These articulations of the concept, and their significance to transition within settlement systems, are described below.

Heidegger's thoughts on dwelling are situated within his body of writing on language, truth, and Being (Hofstadter, 2001; Krell, 1993). Developed as part of a three-part lecture series in the early 1950s, in Heidegger's essays, *Building Dwelling Thinking*, *The Thing*, and *Poetically Man Dwells*, he ruminated on the human relationship to the world at large, as expressed through the preservation and making of things (Krell, 1993). In the first, he searched for a qualitative interpretation of what it means to dwell, and therefore build, arguing that we build only because we dwell. For him, dwelling, and therefore building, naturally entails some degree of systems integration. Through his writing, we get the sense that building as dwelling brings together a series of essential relationships, which are functional, symbolic, and symbolic in their functions. For example, symbolic functionality appears at the point wherein a house becomes a home in the minds of its inhabitants—not simply a space but a place that fosters experiences and contains memories of lives lived: "To clarify, let's call the physical structure, the building itself, the house; and the setting within which people dwell, the home" (Ingold, 2000, p. 185). Heidegger has entreated builders, as dwellers, to be conscientious of the relationships that arise between people and places, such that a general state of harmony is maintained. By the end of the first essay, he had idealized dwelling as a kind of holistic stewardship or preservation: "Mortals dwell in the way they safeguard the fourfold [earth, sky, mortals, divinities] in its essential unfolding" (1993/1971, p. 352). In his philosophy, the constructing of things enacts the essence of dwelling, or the *gathering* of the fourfold: *Relations are enabled through forms*. More so, through building, locations and therefore spaces come into existence, providing a site for the engagement of these primary relations: "The bridge lets the stream run its course and at the same time grants mortals their way, so that they may come and go from shore to shore" (Heidegger, 1993/1971, p. 354, *Building Dwelling Thinking*).

Heidegger's language turns and folds around itself, toying with the reflexivity between his four elements and the mirroring of one within the other through their mutual definition and coordination. The concept of the fourfold is present throughout his writing as the cosmological system to which we are beholden, within which we find meaning through synchronous belonging, and from which we must take measure for the artefacts of our own making (Hofstadter, 2001; Krell, 1993). Underlying this system, we are told, is a great unknown, exposed only in part through the everyday sights and sounds of earth and sky. The mirror-play within the fourfold is depicted as the *ringing* of the world coming into itself, as a unified whole—a phenomenon too profoundly simple to be grasped cognitively (Hofstadter, 2001). As dwellers, he contended, it is our responsibility to uphold the authenticity of things within this interconnected system—to respect and reveal their truth, so to speak. With this, he has encouraged a type of reflective, grounded planning, design, and making, arising in response to, and as a bringing forth of, that which is genuinely meant to be—not driven by human will, industrial production, preoccupation, or dreaming (Hofstadter, 2001). For example, to craft a jug, he has clarified, is to fashion a vessel of offering, along with the many relations this engages: with the earth from which it is made, with the air that fills its void, with the spring whose water it will carry, with the citizens whose thirst it will quench, and with the divinities to which its wine is donated as gift (Heidegger, 2001/1971, *The Thing*). By Heidegger's description, paying regard to these many relations can bring us closer to our world in its making: "If we let the thing be present in its thinging from out of the worlding world, then we are thinking of the thing as thing" (2001/1971, p. 178, *The Thing*). For him, the fundamental nature of an object rests in the parameters of its integration within whole systems: *Relations specify the essence of things*. Thus, we see how Heidegger's portrayal of dwelling could awaken building to a sustainability approach—one that is founded in a reverence for the intrinsic value of the natural world and deliberation of our own fit within.

Heidegger's (2001/1971) essays wrestled with correlations between spirit and substance, and which precedes the other in the manifestation of our known reality. In this way, he evoked a brand of systemic design wherein constructed artefacts transcend their strictly functional and representational qualities. This was not intended as a surrealism or abstraction; Heidegger rejected philosophical detachment from worldly matters, but instead directed his thoughts to concrete issues and historically relevant problems; however, neither did he rely on their strictly quantitative or technical-scientific framings (Hofstadter, 2001; Krell, 1993). Rather, to attend to the prevalent issues of homelessness, job insecurity, political conflict, population growth, the lure of modern diversions, and modern excess, he focused his scholarship on the meaning of Being, with the hope of uncovering a path to authentic human existence—one that recalls our earliest origins (Hofstadter, 2001; Krell, 1993). Heidegger venerated dwelling as a "basic character of Being [human]" (1993/1971, p. 362) or of human presence within the planet and cosmos. At least, this is the essence of dwelling. Through this existence, we are granted the power to gather things together into artefacts of our own design (Krell, 1993). If we are finding these to be crude and ecologically detached, perhaps we could amend this through reflection on our own humanity; in this regard, Heidegger has proposed we turn to the fourfold for inspiration.

To the extent that the nature of our being is profoundly unknowable, so too will the fundamental essence of dwelling remain enigmatic. For Heidegger, the knowledge by which we can take appropriate measure of the world, such that we might dwell humanely within it, is not so much scientific or technological as it is poetic: "…poetry, as the authentic gauging of the dimension of dwelling is the primal form of building" (Heidegger, 2001/1971, p. 225, *Poetically Man Dwells*). Poetic perception, wherein our creative sensibilities are attuned to the properties of the *worlding world*, is his solution to escaping our overly technologized existence (Hofstadter, 2001). Thus, he elevated building to an art form, though not one of mere aesthetic or fanciful imagination. For Heidegger, the poetry of dwelling is the art of precise discernment of the essential nature of things, as they exist in relationship to one another, as well as our place within this interconnected system: *The relations of our dwelling are engendered by the nature of our being*. Of course, we have made some miscalculations along the way. For Heidegger, the current state of dwelling and the socio-ecological challenges that accompany this are not an ultimate expression of its underlying essence; our constructed dwellings may not always demonstrate the best practices by which to manage our own dwelling or existence within the biosphere. To achieve balance between one and the other, he has left us with this task: "The proper dwelling plight lies in this, that mortals ever search anew for the essence of dwelling, that they must ever learn to dwell" (Heidegger, 1993/1971, p. 363, *Building Dwelling Thinking*).

Ingold's (2000) expansion on the dwelling perspective is spread across a collection of essays on livelihood, skill, technology, and what it means for human beings to inhabit an environment—all of which he has presented with the aim of reclaiming an ecology of life. He has defined both, dwelling and the ecology of life, with respect to the immersion and constitution of the organism-person in and from a dynamically unfolding lifeworld. His work continues with the phenomenological tone introduced by Heidegger, though he grounds this by accentuating the coupled relationships that arise between nature and culture, people and places, mind and matter, processes and forms, actions and spaces, past and future. His integrative approach strikes out against Cartesian dualism, which positions nature as an external reality over which cultural significance, or meaning, is organized and imposed. He has likened this dualism to a building perspective—a classic architectural stance whereby "…worlds are made before they are lived in…" (Ingold, 2000, p. 179) or wherein rationalized, procedural, cognitive analyses of places precede our tacit engagement with them. Through colonialism, modernism, and the ascendance of industry, he has suggested, design as an intellectual pursuit now overshadows the physicality of making; so too does the world appear to us as a mere surface for occupation and nature as an object for transformation. As the antithesis to the building perspective, Ingold has positioned human creative acts, inclusive of design and science, as derivatives of both our biological and social existence within the natural world. In other words, science and technological production are embedded within life processes and with the borders between our inner and outer worlds being indistinct. While Heidegger never overtly tied our basic character of Being to the ecosystems in which we dwell, Ingold's adaptation suggests that people, place, and community are, indeed, mutually formative: *Relations are embodied*. As such, the reflexive feedbacks that are common in socio-ecological, complex adaptive, and emergent systems behaviour (Berkes et al., 2003; de Haan, 2006; Jervis, 1997; Levin et al., 2013; Liu et al., 2007) appear more prominently in his framing of dwelling.

Ingold's conception of dwelling underscores the embodied, relational, temporal, and co-evolutionary qualities of creating. Places, or forms, emerge through lives lived over time, in an ongoing state of becoming—never finished. Underlying this is a proposition about systems change that assumes continuity in the evolution and historical development of the human species, societies, and cultural artefacts. What we see in modern systems, he has contended, belongs to this process of unfolding as much as the huts of our early ancestors and is no less natural. Human lifecycles and daily activities (or taskscapes) are embodied within the inhabited physical environment (or landscapes), with tasks being the constitutive acts of dwelling. Ingold has portrayed the taskscape as a suite of time-based movements that occur within a place, propelled by the rhythms of social life, and as they are connected to the cycles of local ecosystems. The landscape, on the other hand, is the form that becomes the site of these dynamic processes, with its features being incorporated into routine patterns of behaviour. Its spaces and places are fluid, not fixed—suspended in movement, as Ingold has put it. Neither are their boundaries defined, with clear beginnings and endings. Rather, they present as connected centres of activity, lighting up across regional networks: *Relations emerge and extend through time-based action in space*. This leads us in a similar direction as contemporary science of cities work, which is increasingly looking to analyse forms as an outcome of flows (Batty, 2013a).

> What it means is that the forms people build, whether in the imagination or on the ground, arise within the current of their involved activity, in the specific relational contexts of their practical engagement with their surroundings…The 'final form' is but a fleeting moment in the life of any feature, when it is matched to a human purpose, likewise cut out from the flow of intentional activity. (Ingold, 2000, p. 186–188)

While Ingold's thinking is evocative of complexity science, he too has proposed a *poetics of dwelling*. Taking inspiration from traditional indigenous ways of life, he has explained that this poetic understanding can be drawn from our experiential engagement with the world. For example, in some hunter-gatherer communities, technology, society, and nature are closely entwined; so too do myth, dream, and performance contribute to processes of sensemaking, with respect to human-environment relations. In some indigenous communities, he has told us, the meaning, or essence, of things may shift, relative to their purpose and associations with other things: *Relations are coordinated symbolically, as well as functionally*. Through the dwelling perspective, he has attributed this to Western societies, as well: "…meaning is immanent in the relational contexts of people's practical engagement with their lived-in environments" (Ingold, 2000, p. 168). Places (whether wild, rural, or urban) come into being as homes by virtue of our dwelling within them; the memories of our social histories impregnate their spaces. Ingold's poetics also infers a *resonance* between individuals, society, and the natural world. By this, he means that everything is in its right place, operating in concert with the remainder of the system. Thus again, the poetry of dwelling is, effectively, a systems view of life, enriched with a cosmological angle.

Though their sources of inspiration differ, as do their cosmological touchstones, Heidegger and Ingold offer comparable conceptions of dwelling. From both, we are granted a temporally articulated sense of being in the world, as enmeshed within a series of meaningful relations (Ingold, 2000; Krell, 1993), by which places and things emerge. Both authors endow humans, as productive agents, with the power to organize or *gather* these relations, whether through preservation or transformation; however, they also underscore the imperative to ground knowledge and decision-making in an intimate attunement to context. Further to this, design is seen as a discovery of that which is meant to be, or a revelation of truth, as opposed to the imposition of our creative will on the world. (This bears some connection to the concepts of the adjacent possible or design space,[16] which suggest that prospects for innovation exist before we have realized them.) They also aim to complement technical-scientific or rational-quantitative ontologies, exploring how direct experiences of consciousness, being, and enlightenment can be foundational to the nature of dwelling. Heidegger has presented his thoughts on dwelling to connect acts of building with the meaning of Being; Ingold has done so to counterbalance the tendency of Western thought and design to prioritize the development of forms over the analyses of processes.

More recently, the dwelling perspective has made its way into resilience scholarship, which is significant as a step by which we can align resilience thinking with urban planning. These scholars (Cooke et al., 2016; Davidson-Hunt & Berkes, 2003) have adopted the concept to articulate the complexity of human-environment interactions and facilitate our re-embodiment within natural systems, or to forward a human-in-ecosystem approach to management, with a focus on dynamic processes. Generally, their thinking reacts against nature/culture dichotomies, and the alleged need to keep people out of natural environments (see Hobbs, Higgs, & Hall, 2013). For these authors, tacit and sensory engagement with the biosphere can serve as an antidote to overly cognitive methods in sustainability and resilience planning and stimulate local action (Cooke et al., 2016). In other words, they advise putting our hands in the mud as reminder that it is this same earth that grants us life. They carry on with the same basic premises as Heidegger and Ingold, though with a view to local and global ecosystems management: that we should engage in land-based learning as a means of shifting mindsets; that features of environments appear through patterns of activity; that sense of place is emergent from relational experi-

[16]*Design Space*: The total set of prospective designs that could be rendered (Beinhocker, 2011).

ences (Davidson-Hunt & Berkes, 2003); and that the biosphere is dynamically co-produced through human-environment interactions, occurring at different spatial and temporal scales (Cooke et al., 2016).

There is a contextual predisposition in Ingold's writing, which other scholars have latched onto. Namely, the common presumption is that the dwelling perspective applies primarily to small, traditional communities, subsisting on land-based livelihoods, wherein connection to the natural environment is direct and explicit (Cooke et al., 2016; Davidson-Hunt & Berkes, 2003; Obrador-Pons, 2006). Certainly, Ingold's essays are most suggestive of these types of scenarios, as many of them are based on discussions of rural or traditional hunter-gatherer societies. However, his core premises can still apply in contemporary, industrialized settings, regardless of our supposed cultural and spatial detachment from the natural world. In fact, he has stated himself that industrial machinery and material paraphernalia form part of the dwelling context with which humans must learn to cope. The concept of dwelling can challenge us to assess how human life within the biosphere has scaled up and out, over time, and whereby distances between people and places have become compressed by virtue of technological advancement (see West, 2017). Conversely, if we assign it exclusively to our localized and immediate engagements with the natural world, we risk overlooking cumulative, globalized phenomena in project planning (Cooke et al., 2016). Processes of dwelling extend across space and time: The fields of relations they engender would be all of those within the globalized human-environment web. Dwelling is heterogeneous, in that there is no one way to dwell within each of the biosphere's many biomes or cultural contexts; however, together as a human community, we have entrenched some of the parameters by which we do so. The concept of dwelling reveals the tension between managing localized and globalized systems phenomena. To reconcile this, Heidegger, Ingold, and Cooke et al. have offered similar solutions, as follows: Our nearness to or intimacy with things is not a spatially dependent occurrence, rather something that is achieved by accounting for all of our relations (Heidegger, 2001/1971); so too do we become at home in a place when we orient our actions to the relations of the taskscape, or our lifeworld, as opposed to the technologized, routinized, capitalist system of production (Ingold, 2000); to synchronize the local with the global, we can consider how to operationalize the planetary boundaries framework (see Steffen, Richardson et al., 2015) within the context of these lifeworlds (Cooke et al., 2016). These recommendations rest on an ontology of engagement rather than detachment—from experiencing the world from within, as opposed to analysing and managing it from above (Ingold, 2000).

> …the local is not a more limited or narrowly focused apprehension than the global, it is one that rests on an altogether different mode of apprehension—one based on practical, perceptual engagement with components of a world that is inhabited or dwelt-in, rather than on the detached, disinterested observation of a world that is merely occupied. (Ingold, 2000, pp. 215–216)

If applied in urban planning, the dwelling perspective could alleviate the primacy of forms, instead, considering the ranges of human thought and action that contribute to the production of an ever-evolving environment; how *processes of settlement* have led to the *formation of settlements*, which enable further *processes of* *settlement*; and, how these processes have integrated with or disintegrated from other biosphere phenomena. If settlement is analogous to dwelling and dwelling is oriented around fundamental processes of human life, as embodied within environments (per Heidegger's basic character of Being or Ingold's taskscape), then a socio-ecological science of human settlement could, by this right, be inducted from a science of human life within the biosphere. One weakness of the dwelling perspective is its tendency to project an apolitical flavour. For example, Heidegger (1993 /1971, 2001/1971) has painted his world like a mythology, with human agents taking the stage in service of a greater plan; in Ingold's essays, the messier dimensions of human behaviour are subsumed under a field of task-based action. Though his work did not reference dwelling, in particular, Doxiadis' (1970, 1974) five principles of settlement give some indication of what the related universal processes might be; however, like the others, he leaves us without a strong sense of the identities or proclivities of systems actors. Instead, his mechanisms of systems change revolve primarily around the proverbial man's calculated attempts to achieve maximization, minimization, or optimization of human-environment interactions. In revisiting his initial conceptualization of dwelling, Ingold (2005) has discussed the challenges of accounting for factors such as power relations and makes some effort to incorporate a political dimension:

> Dwelling encompasses building just as producing life encompasses the production of the material means by which it is carried on. And of course, Marx went out of his way to emphasise how the production of life is not only essentially social but also structured by power relations. (Ingold, 2005, p. 504)

In expanding a socio-ecological science of settlement, we could aim to articulate the *human life* processes from which settlements emerge, in all of their complexity.

Systems Dynamics as a Basis for Place

In revisiting the dwelling perspective, approximately a decade following his first essay on the subject, Ingold (2005) reasserted his relational, process-oriented intentions, pushing back against any lingering misperceptions that the concept evokes a secure place of rest. His compunction to do so reveals a key challenge for planning: to balance between the concrete and the ephemeral, the material and the energetic, the static and the dynamic, the enduring and the fleeting (Obrador-Pons, 2006). The concept teases at either side, with Heidegger's (1993/1971) search for essence and Ingold's (2000) emphasis on process. Neither author relieves us entirely of our responsibilities to the classic design interests of form, space, materiality, and aesthetics; however, both compel us to descend from our constructed realities into the socio-ecological phenomena they embody, whereby we can analyse reflexive relationships between structures and flows, forms and meanings. The section to follow explores intersections between the concept of dwelling (which originated in phenomenological philosophy) and the evolving suite of science of cities methodologies (which could be drawn from quantitative, qualitative, and design-based approaches).

The Social, the Ecological, the Constructed

Architect Christopher Alexander (2002–2005) has sought to uncover life processes, or *life-enhancing* design processes, in his own practice, which he explains in his four-volume series, *The Nature of Order*. Through this extensive writing, he has described how to let design schemes unfold gradually, as one comes to know the local ecosystems and communities with which one is working, or to allow built form to extend out of nature and culture. Alexander's approach to building illustrates a contemporary and applied rendition of the philosophies underlying the dwelling perspective. For example, in the making of things, he aims to tune into the intrinsic nature of people, place, and form. For him, these central qualities are objective and specific, though tenuous to identify or label. Rather, he deliberated at length on how to perceive them, if only intuitively, through design process. Spaces created with meticulous consideration of these qualities, in every sensory detail (sight, sound, smell), he believed, connect us with the truth, beauty, and austerity of our own existence. To design in this way is to breathe life into a place, such that it becomes healthy and self-reproducing, not wretched and self-destructive. As was introduced in Ingold's thinking, in these living systems, the essential qualities of independent parts will be enhanced through the arrangement of the whole. Thus, Alexander's sustainable architecture is a relational one. Always customized to context, his approach is the antithesis to mass production and epitomizes what some might refer to as slow or adaptive design—the first which reveres quality in creation and connection (see Honoré, 2004) and the second which encourages responsiveness to dynamic contextual factors (Lister, 2013/2010). Though Alexander's writing elaborates considerably on holistic, systemic, and bio-conscious approaches to urban and architectural development, it also exposes some of the limitations of design for engaging in rigorous socio-ecological systems analyses. Throughout his four volumes on life-centric design philosophy and practice (Alexander, 2002–2005), we are afforded only a glimpse of the substantive content of our social and ecological worlds. Geddes too was regarded for his environmental ethic, attention to the influence of people and place on one another, and holistic interpretation of planners' responsibilities to social wellbeing (Hysler-Rubin, 2011). However, regardless of designers' sense of principle, we ultimately face Alexander's (1964) original methodological conundrum: to navigate form-context boundaries and delineate the sites of our interventions within dynamic settings. To do so, it is worth extrapolating the point at which a science of design should bleed into a science of that for which we are designing—the social, the ecological, the technological.

Part of the challenge is that design crosses into natural, social, and humanities' disciplines, yet remains distinct from any of these fields in its focus and methods (Buchanan, 1992; Cross, 2007; Nelson & Stolterman, 2012). As well, design outcomes are conventionally associated with things that are neither explicitly human nor natural, occupying instead the world of the artificial (Simon, 1996/1969). When Simon explained design as a *science of the artificial*, he aspired to grant it with a procedural, problem-solving logic "that would be acceptable to a community of engineers" (Margolin, 2002, p. 235). His efforts to do so came among others, who similarly wished to venerate design as a legitimate and distinct field of scholarship while also codifying its methods of practice and setting it apart from softer approaches to decision making (Edmonson, 2007/1987; Margolin, 2002; Mehaffy, 2008). This dichotomy is paralleled in what Portugali (2011, 2012a, 2012b) has termed the two cultures of cities/planning. Namely, these represented a clash between quantitative and qualitative camps, batting against each other in the late half of the twentieth century. On one side, there were positivist, quantitative analytic and rational comprehensive approaches, which sought to define the ideal city, and the optimal procedures by which it should be planned. On the other, there were social theories of cities, which painted political, pluralistic, humanistic, experiential, and philosophical views of urban systems and analysed macro-level social phenomena. There is also a third way, he contended, reflected in the work of the occasional, nonconformist luminary, for example, who highlighted bottom-up processes of development (Jacobs), the complex network structures that result (Alexander), and the routine space-time movements that act as a weak generative force on the city (Hägerstand) (Portugali, 2011). As methodologies, there is potential for integration, and Portugali (2000) has proposed that self-organizing theories of cities can serve as the bridge. If we were to take the above-mentioned cultures of cities/planning as a methodological package—examining globalized social trends, localized diversity, dynamic social networks, and properties shared with other complex systems—the key missing lens, still, would be analyses of ecological contexts. However, recent resilience-based approaches to urban ecology are filling this gap, with a view to contributing to science of cities thinking (Elmqvist et al., 2013a; McPhearson et al., 2016).

For practitioners designing conscientiously, or in accordance with a sustainable design mindset, it would be normal to assess site conditions and multi-stakeholder priorities in advance to project development and with reference to planning goals. We can pay regard to environments and people and include communities in creative processes. We might even consider this a traditionalist approach, with its lineage tracing to the work of Geddes: "A town or city in some sense grew out of its urban and rural environment in a complex web of causes and effects, its inter-related parts interwoven through time" (Batty & Marshall, 2012, p. 24 with reference to Geddes). Yet, each of these domains, the social and the ecological, is a world unto itself and could take a lifetime of study to understand. Their dynamic, intersecting behaviour is another matter, altogether, and methods for the empirical analyses of feedbacks between social and ecological systems, or between ecological and technological systems, are still nascent, within urban fields and otherwise (Elmqvist et al., 2013b; Gallopín & Raskin, 2002; Levin et al., 2013; Liu et al., 2007; Rotmans et al., 2000). This is understandable. In a globalized setting, these feedbacks have become increasingly complex (Gibson, 2016; Young et al., 2006), and the profession of planning is not alone in its minimization of ecological considerations; for example, Olsson et al. (2017) have indicated that social innovation initiatives, too, have thus far been lacking in their attention to dynamic human-environment interactions or integration of social and ecological factors. This is changing, as a new domain of innovation and invention takes shape, which combines social and ecological mandates—socio-ecological innovation (Olsson et al., 2017).

In fields related to urban planning, design and study, nature, society, and technology have been merging through hybrid disciplinary approaches, such as urban ecology (Grimm et al., 2008; McPhearson et al., 2016; Mostafavi & Doherty, 2013/2010; Niemelä et al., 2011), landscape urbanism (Waldheim, 2006), biophilic design (Beatley, 2016; Kellert et al., 2008), and biomimicry (Benyus, 1997), along with efforts to reinsert humanity into industry (citiesforpeople.ca; Ellard, 2015; Gehl, 2013; UN-Habitat, 2014). Thus, planners and designers are acting to reform settlement systems on both sides of the nature/culture equation or the two rings of the planetary boundaries doughnut (the ecological ceiling and the social floor) (Raworth, 2017). We have recognized the impacts of the built environment on physical and mental health, linked to factors such as air pollution, sanitation, access to green space, active transportation, and cultivation of ecosystems functions and services (McPhearson et al., 2016; Rojas-Rueda et al., 2016; Tzoulas & Greening, 2011); that citizen wellbeing is an outcome of multiple intersecting factors, inclusive of but not limited to community context, engagement, socioeconomic status, and equity (Bromell & Cagney, 2015; Duhl, 1996, 2005; Kelley-Moore, Cagney, Skarupski, Everson-Rose, & Mendes de Leon, 2015; UN-Habitat, 2014); that urban design can contribute to citizen quality of life (McCormick et al., 2013); that cultural development and expression can derive both economic and social benefit (Florida, 2008); and that urbanization processes continue to place pressure on climate systems, biodiversity, coastal regions, ecosystems services, and agricultural production (Elmqvist et al., 2013a; Sassen, 2009). In our strategies to enable sustainable urban development, it would seem as though we are being categorically comprehensive (also see the list of targets and indicators for SDG Goal 11); if this is not propelling us towards a sustainable future as rapidly as we would hope, perhaps we are overlooking something within the coupled dynamics of social and ecological factors, the indirect impacts of the social realm on the environment, or the emergent properties of settlements.

For example, more elusive than planning sustainable cities is the task of re-embedding culture within nature; although, this is effectively what a number of research-practitioners have been attempting under mantras to design with respect to, or inspired by, living environments (arcosanti.org; Alexander, 2002–2005; Beatley, 2016; Benyus, 1997; living-future.org; McDonough & Braungart, 1992, 2002, 2013; McHarg, 1995/1969; Register, 2006; Todd, 1985; van der Ryn &

Cowan, 1996; Wann, 1996). In sustainable development, the conceptual construct of city has the potential to mislead our initiatives or at least cut them short. As a moderation, the lens of dwelling would ideally trigger intuitive responses by which to mitigate the nature/culture divide, within the setting of constructed systems, or intimate approaches by which to "fundamentally rewire human-environment relationships" (Olsson et al., 2017, p. 31). The complication with this, however, is that the link between one and the other, nature and culture, in human-environment interactions is not always direct (Liu et al., 2007; McDonald et al., 2013). More accurately, these relationships could be described as human-to-human-environment interactions or even human-to-human-environment-to-environment interactions; not to mention, somewhere between one and the other sits technology. Settlements are comprised of multiple, intersecting complex adaptive systems: "...the city as a whole is a complex system and each of its agents is also a complex system" (Portugali, 2016, p. 3). Any comprehensive science of settlement should, presumably, endeavour to deconstruct the dynamic layers of each, as well as the interaction among them. A science for the design of settlement systems could, effectively, be a science of the socio-ecological systems complexity within which we are designing.

Integrated Essence

It is not surprising that the dwelling perspective was initially conceptualized without significant representation of power dynamics, seeing that the term *human-environment interactions* similarly compresses these, as has resilience scholarship (Cooke et al., 2016; Wilkinson, 2011). The human dimensions of sustainability and resilience are too disparate to cover in one line of disciplinary inquiry: There are meta-layers to the social realm that are auxiliary to our basic survival. Neither is the impact of human activity on the environment always immediate nor localized (Elmqvist et al., 2013b; Mascaro et al., 2013; Perring & Ellis, 2013; Seto et al., 2012); some effects will be measurable, though we can also presume that the chain of causality will be dispersed among a broad field of endeavour and behaviour. Design, innovation, and planning practices confound these factors further, in that they mediate, and sometimes dislocate, our connection to the natural world (Liu et al., 2007). Furthermore, as the technologies and schematics by which we support human life continue to propagate, the significance societies attach to related forms could also evolve. The automobile presents a clear example of this—a technology that now holds social value beyond the fulfilment of our pragmatic mobility needs. To the extent that meaning is embedded within our constructed realities, designers are caught in an ontological feedback loop: Design sits on the leading edge of not knowing where we want to go; the possibilities it reveals may fuel latent desires. Furthermore, along this path of innovation, we may forget to stop along the way to contemplate what it all means—at least until the cumulative effects become apparent.

Heidegger (2001/1971) and Doxiadis (1974) hinted at this in their efforts to ascertain the essence of dwelling (or settlement). By definition, essence is "the real or ultimate nature of an individual being or thing…as opposed to its existence or its accidental qualities," and "the properties or attributes by means of which something can be categorized or identified" (Allen, 2006, p. 474). In effect, these two authors were grasping to pinpoint the aspects of settlement that are, more or less, enduring, regardless of systems change—those that transcend time and context. In their writing, as well as that of Alexander, this essential nature of settlement, or built form, is discussed as something that is real, yet intellectually inaccessible; for them, it may remain as elusive as the nature of human nature or being (see Doxiadis, 1974; Hofstadter, 2001). Complexity theories of cities have been working in this same accord and have revealed common properties and mechanisms of urban growth, scaling, form, and organization, which repeat across space and time, as well as patterns of behaviour that are shared with other complex systems (Batty, 2013a; Batty & Marshall, 2012; Bettencourt, 2013a, 2013b; Portugali, 2000, 2012a, 2016; West, 2017). This quantitative research does, indeed, offer some perspective on the essential nature of cities, as complex adaptive systems, though mainly focused on their general structures, properties, and dynamics, as opposed to their substance and specific qualities, which are matters for qualitative inquiry. Purportedly, repetition of quantitatively or qualitatively measurable factors would be the necessary criteria for the expression of a science. In searching for these, however, we should caution to distinguish the fundamental essence of dwelling (or settlement) from the many variations by which it has transpired. After all, the current state of urban systems may not be the epitome of urbanism (Sassen, 2012).

Partly, this is a dilemma for systems thinking: The whole of the city is greater than the sum of its individual parts. There may be integrative, relational, or emergent factors that are critical to its essence, appearing at the aggregate level and rendering urban planning different from object-based design endeavour (Batty & Marshall, 2012; Bretagnolle et al., 2009; Portugali, 2012a). As problems in *organized complexity*, the patterns that emerge within cities through the interrelation of innumerable factors are quintessential (Jacobs, 1961). Taken as such, there is a question as to whether essence and function are historically dependent and evolving. Do the nature and purpose of settlements, and our dwelling within them, change along with their repatterning? Urban sociology, past and present, has drawn attention to the major social processes that have brought with them new order within urban contexts, such as industrialization, digitization, and globalization (Sassen, 2010). At the same time, the similarity in features, composition, and logic between ancient and contemporary variations of cities, despite more than 5000 years of change (Portugali, 2000), raises the question as to whether urban systems encapsulate something that is intrinsic to human life. In this respect, following from Max Weber, Portugali (2000) classifies cities not based on their strict conformity to a list of features or criteria, rather as derivatives of an ideal type,[17] which arise within

[17] *Ideal Type*: In this method of analysis, a model exemplar of a given social or cultural phenomenon is identified, against which other instances can be compared and connected. Sociologist and

culturally and historically specific conditions. Others have noted a similar quandary with respect to studying the nature of human nature, and how we might do so without reducing interpretations to a list of attributes shared among all members of the human population (Capra, 1996):

> …the real problem would be 'to infer the *core* common to the whole human race from the innumerable manifestations of human nature…to recognize the laws inherent in human nature and the inherent goals of its development and unfolding [E. Fromm]'. (Capra, 1996, p. 56)

Though not obvious to combine within disciplinary contexts, these two areas of inquiry, settlements and human nature, are closely related, if only by the simple adage that cities are people (Jacobs, 1961; West, 2017). Further, we may discover new approaches for examining the relationship of each to sustainability, through their mutual association. If we associate settlement with dwelling, and dwelling with (human-to-)human-environment(−to-environment) interactions, and human-environment interactions with human life within the biosphere, we may ultimately discover means of answering questions about one with the other. For example, could we extract general premises about our own humanity based on the ways we have organized in space, over time, within the context of settlements (i.e. our ways of *being in the world*), or determine the best means of managing systems of settlements through analyses of ranges of human-environment interactions (i.e. the crux of sustainability)? Doing so might provide more empirical grist (see Sassen, 2010) when attempting to address the complex human dimensions of sustainability and resilience challenges and refine classification of the kinds of issues we are endeavouring to solve—reducing redundancy in our framing of the problem space while also inverting it. If settlements are sites wherein globalized social phenomena take effect (re. Sassen, 2010), through these systems we are granted access to complex and emergent social trends. Furthermore, if settlements are an embodiment of human-environment interactions, we can explore, more precisely, how these have been entrenched in physical space. We may even find that readings of our constructed worlds reveal to us our own implicit preferences or that changes in systems of settlements, over time, continue to liberate aspects of human experience that were unattainable in earlier systems states (whether desirable or undesirable).

Between their essence and schematics, systems of settlements have yielded contradictions. For example, they bring people together (Bettencourt, 2013b), yet produce experiences of social alienation (Montgomery, 2013). They enable economies of scale through the sharing of resources (Bloom et al., 2008), yet perpetuate socio-economic segregation (Harvey, 1985; McCormick et al., 2013; UN-Habitat, 2014). They have facilitated an impressive range of human achievement (Bretagnolle et al., 2009; West, 2017), yet at a pace of globalized development that is overtaking our ability to manage the impacts (Young et al., 2006). They exhibit lower per capita carbon emissions (West, 2017), yet are reproved for poor air quality. They have

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political economist Max Weber analysed cities in this way, wherein he illustrated how those arising within very different times and places could be related through their shared characteristics, as opposed to generalized laws (Portugali, 2000).

fortified the human capacity to survive within and spread out across multiple niche ecosystems (Christian, 2004; de Vries & Goudsblom, 2002), yet the means by which they have done so are now compromising their long-term resilience (Elmqvist et al., 2013a). These incongruities speak to the paradoxical behaviour of cities, in particular, as they engender both challenges and opportunities for transition. This appears as a central narrative within science of cities thinking, which highlights one key tension exposed by the universal, superlinear, and sublinear scaling properties of urban systems: That is, as cities grow in size, they exhibit an exponential increase in certain desirable attributes (such as economic productivity and innovation) and similarly in undesirable ones (such as crime and traffic congestion) (Bettencourt & West, 2010; West, 2017). Returning to the question of essence, we could debate whether these listed attributes are intrinsic to any city or a product of how we have organized urbanism. The above contradictions and tensions signify a possible disjuncture between the current state of urban systems and their potential or between their existing variations and underlying nature. The learning curve along which they have matured has perhaps embedded systemic dysfunctions.

> [A contradiction is] a set of problems or tasks that cannot be resolved within the terms of reference (or 'paradigm') in which they are conceived… In the case of modern Western civilisation, there are two that are linked: the moral unsustainability of a lifestyle that most of the planet's people cannot ever enjoy; and the physical unsustainability of that lifestyle even for the (temporarily) fortunate minority. (Ravetz, 2007, p. 281)

Generally, it is deemed imprudent to pursue a paradigm shift as a course of habit, as opposed to something that unfolds through cumulative, collective discovery and action (Kuhn, 1996/1962; Meadows, 1999). However, we could certainly inspire change by engaging with complex problems through the application of new concepts, research methods, strategies, and/or practical techniques. For the two issues he has mentioned in the above quote, Ravetz (2007) has criticized the green-tech and localized, do-it-yourself solutions typically proposed, respectively, on the basis that neither has the capacity to fix nor transform rigid or degraded systems conditions. To endorse a possible paradigm shift, he has made one off-the-cuff recommendation for altering both sides of his linked contradiction: "…a revolution of consciousness, whereby affluence itself came to be seen as a disease" (Ravetz, 2007, p. 283). In other words, he has tentatively urged us towards the transformation of our current economic system—experiments for which are already underway through the auspices of ecological economics (Brown & Garver, 2009). Ravetz (2007) has presumed that acquisition of affluence, or capital wealth, occurs primarily through engagement with an economy that exploits nature as well as vulnerable communities. Ostensibly, this is the current state of the system, rather than its essence, however. It may be possible to construe other, nonmonetary forms of wealth, for example, as represented in ecological economics literature as natural and cultural capital (Berkes et al., 2003).

So, how does this relate to our science of settlement and help reconcile the tensions posed by contemporary urban systems? It comes back to Sassen's (2012) point about content: It may not be urbanism that is problematic, so much as the means by which it has been conceptualized and accomplished. Our characterizations of the substance of a system will inform how we measure its performance. For example, gross domestic product (GDP) statistics, which are featured in urban scaling research (Bettencourt, 2013a), have come under scrutiny as a limited and outdated measure of the wealth of nations (Brown & Garver, 2009; Henderson, 1995); as an indicator, it is loaded with significance that some find contentious, for example, having objected that the productivity of the informal economy, or the value of social and natural capital, remain under-represented (Elmqvist et al., 2013a; Henderson, 1995). So too would something like crime have a context-dependent definition (Bettencourt, 2013b) and a variety of socioeconomic determinants. Finally, an example that is most illuminating of why content counts is found in a series of graphs on urban scaling—ones that illustrate the sublinear distribution of gasoline stations within Europe (see West, 2017). Clearly, the presence of this particular infrastructure is a phenomenon of the fossil fuel era; substantively, it is a modern outcome. Yet, its distribution within cities follows a mathematically predictable pattern, in accordance with city size; quantitatively, it exhibits a property that adheres even in cities of the past (see Bettencourt, 2013a, 2013b). In other words, scaling properties of cities have held across time, despite obvious modifications to the content of urban systems. To blend qualitative with quantitative insight, we could investigate whether comparable transportation infrastructure and energy technologies, of another era, conformed to this scaling behaviour and whether societies of the past were meeting analogous functional needs in similar ways. Also notable is the relevance of the gasoline station to urbanism and its role in the production of society and civilization. These kinds of qualitative questions could be developed to complement the existing body of quantitative research on scaling properties: For example, many of the phenomena that have been graphed would be multifaceted in their formulation, arising through series of relationships greater than the sums of their parts. Nurturing the desirable while mitigating the undesirable aspects of urbanism, therefore, calls for an integrated approach. The outcomes of urbanism are fundamentally relational, and many would be reflective of emergent patterns.

Form, Matter, Process, Meaning

Complexity and resilience scholars have been honing methods for tracking dynamically evolving systems and noting when they are verging towards fundamentally new states (see Scheffer, 2009), while, in design and innovation work, we may attempt the intentional facilitation of such transitions, especially within human-constructed systems. In both cases, we come up against the same predicament of distinguishing one state from another and assessing the relative complexity, novelty, diversity, sustainability, and resilience of each. Extending from the dwelling perspective, we could propose an integrated means of doing so—one that links with both science and design-based thinking; could bridge social, ecological, and technological considerations; and could be applied to assess multiple systems types. The dwelling perspective evokes a methodological position that presumes interrelation between meaning and function and incidentally overlaps with those already present within a few other fields. Across strategic design, social innovation, complexity, systems thinking, and transition literature (Beddoe et al., 2009; Brown, 2009; Capra, 2002; IDEO, 2015; Loorbach, 2010; Odum 2007; Westley & Antadze, 2010; Westley et al., 2007; van der Leeuw et al., 2009), we find comparable categorical frameworks for deconstructing complex systems features, phases of systems change, areas for multi-stakeholder action, and/or actor roles. Elsewhere, I have synthesized these categories as *perspective*, *practice*, and *power*; another common classification cluster is *information*, *matter*, and *energy* (Odum, 2007). In all cases, these frameworks have aimed to comprehensively capture the parts comprising complex wholes, in a way that is universal and generalizable (though are not expressly empirical in their formulation). Analysing integrated phenomena on simple, yet astute, terms may ultimately help expose the roots of the contradictions emerging through contemporary urbanism.

Within this set, there is one framework, in particular, that aligns overtly with the dwelling perspective and has been presented with the similar intention of sparking a paradigm shift for sustainability. The related shift that has been unfolding within science and design is the relinquishment of Cartesian dualism, which is part of what initially spawned division between the realms of nature and culture, in both scholarly and creative work (Capra, 1996, 2002; Davidson-Hunt & Berkes, 2003; Ingold, 2000). Where Ingold (2000) has criticized design for prioritizing forms over processes, according to Capra (1996, 2002), a parallel fragmentation exists in Western science and philosophy, between the study of substance and form, the material and the non-material, and matter (natural) and behaviour (social). For him, we can achieve balanced analyses of life phenomena (inclusive of the biological, cognitive, and social) through the combined observation of their *form*, *matter*, *process*, and *meaning*, as well as the interrelations between these elements.[18]

> …culture is created and sustained by a network *(form)* of communications *(processes)* in which *(meaning)* is generated. The culture's material embodiments *(matter)* include artifacts and written texts, through which meaning is passed on from generation to generation. (Capra & Luisi, 2014, p. 304)

More so, he has contended this unifying framework is necessary for sustainability planning, to synchronize social organization with the biophysical world. By analysing social and ecological systems in accordance with comparable parameters, we might explain how each is like the other, constitutive of the same general elements. Thus, we reduce redundancy within our problem domain, both conceptually and methodologically. Patterns of settlement, and the relative complexity these engender, could be examined as an outcome of the dynamic, ongoing, reflexive interaction between these four elements. As with dwelling (social) *beings* and *world* could be

[18] *Form* is the physical embodiment of a system's pattern of organization; *matter* is the material structure of a system; the *process* of life is the activity involved in the continual embodiment of the system's pattern of organization; *meaning* is the inner world of reflective consciousness (derived from Capra & Luisi, 2014, pp. 303–304).

viewed as co-evolving, with the products of modern society emerging within this continuum (re Ingold, 2000).

To illustrate a simple application of this approach, I will return to the contradiction presented by Ravetz (2007), introduced earlier. For him, affluence as a concept is associated with a globally institutionalized, economic system, which includes some and excludes others, leading to social inequalities and instances of extreme poverty. If we were to identify the limiting resources (re Simon) applicable in this case, we might start by considering the pathways by which impoverished, underdeveloped communities could improve their circumstances. Lawyer Hernando de Soto (2000) has done just this: Working initially with communities in Lima, he noticed the assets of informal settlements were not being accounted for within legal, and therefore economic, systems, rendering it more difficult for these low-income citizens to participate in the market economy. To address this, de Soto established legal property titles for their shantytown dwellings, thus providing them with assets against which they could hypothetically leverage credit and loans (Fernandes, 2002; Mau et al., 2004).

> …shanty homes are essentially economic assets, 'dead capital', that should be revived by the official legal system and turned into liquid capital so people could gain access to formal credit, invest in their homes and businesses, and thus reinvigorate the economy as a whole. (Fernandes, 2002, p. 6)

Without reorganizing or intervening within their physical dwellings (form/matter), de Soto modified the legal status of their properties (meaning), thus altering residents' ability to engage with the market economy (process). He has mitigated Ravetz's (2007) contradiction while working within the parameters and opportunities of conventional economic and legal systems. Some criticize his approach as being overly conservative, under-analysed, unrealistic, and one-dimensional (Fernandes, 2002). Still, by ascribing one thing (informal settlements) with new significance (legal titles), de Soto endowed it with enhanced functionality and benefits. He also introduced socioeconomic complexity to these developing world contexts.

The dwelling perspective exalts the *field of relations*, in which both nature and culture are inevitably entangled, as a worthy subject of study and site for innovation (Ingold, 2000). If a paradigmatic transition is burgeoning in design—and with due regard to the influence of Jacobs (1961), who considered processes to be of the essence to urban planning—it is that practitioners are similarly looking to reveal the relationships embodied within our constructed realities. Phillip Beesley (2017) has employed the term (field of relations) to describe a renewal for architecture, no longer confined to the creation of buildings carried eternally on firm ground (as once depicted by Vitruvius), but also engaged in the production of semi-organized nuclei of exchanges (material and energetic)—a living architecture, though still emplaced. In a similar vein, Lally (2014) has explored how to shape energies (electromagnetic, thermodynamic, acoustic, and chemical), as well as social interactions within space. Urban planner and geographer, Michael Batty (2013a), has entreated us to turn our attention from urban artefacts to flows: "…instead of thinking of cities as sets of spaces, places, locations, we need to think of them as sets of actions, interactions, and transactions that define their rationale and relate to the way scale economies generate wealth…" (p. 9). Tomalty (2009b) has recounted how urban sustainability initiatives are progressing beyond isolated issues (e.g. with recycling or conservation programmes), instead diving into the "…underlying processes that structure our relationship with nature…" (p. 19). Rotmans et al. (2000) have offered an integrated planning tool for sustainable cities, which evaluates systems stocks and flows (economic, sociocultural, ecological), to complement the narrow focus on urban environment and infrastructure that is common in conventional approaches. Urban metabolism research is maturing from analysing stocks and flows to predicting or directing them: "The challenge ahead is to design the urban metabolism of sustainable cities" (Kennedy, Pincetl, & Bunje, 2011, p. 1971). In Mau's (2010) portrayal of sustainable design, practitioners create artefacts with a view to their positioning within broader cycles of production and consumption. Sevaldson (2016) has codified general types of systems relations for designers (structural, semantic, social, hard) and has suggested ways by which these might be quantified and qualified. Of course, a core tenet of ecological design is to integrate "'…human purposes with the larger patterns and flows of the natural world'" (D. Orr in Capra & Luisi, 2014, p. 442). In short, underlying this shift is the idea that relational systems dynamics could be a subject of both empirical observation and substantive modification, within design-based projects. Moreover, through relational approaches, we may begin to view settlement systems as dynamic, living entities:

> Infrastructure is akin to a living system that brings increasing numbers of people together in more complex economic and social relationships. (Rifkin, 2011, p. 35)

There are a number of compelling reasons to undertake relational analyses between form, matter, process, and meaning, as these pertain to sustainability and resilience within settlement systems, especially if our goal is to disrupt prevalent models. The first is to examine how the state of a system entrenches *power*, as is revealed by Ingold's (2005) comment: The "production of the material means by which [life] is carried on…is structured by power relations" (p. 504). For example, these appear in our harvesting and distribution of natural resources (i.e. cycles of production and consumption), as well as our shared social spaces, in the way they en(dis)able participation in civic life. The second is to examine how the state of a system entrenches *values*. For example, we may perceive the significance of a thing, like an automobile, relative to its various practical and social uses. The third is to examine how the state of a system entrenches *functions*. For example, daily commuting and the transportation infrastructure that supports this are very much tied to the nature of citizens' formal participation in the economy. The fourth is to examine how the state of a system delivers *benefits*. Of course, part of the lure of urbanization has been the increased life opportunities it theoretically engenders for citizens (Jacobs, 1961). The fifth is to examine how the state of a system entrenches *cumulative impacts*. Traffic congestion resulting from sprawling development would be one example of this. The goal of such analyses would be to identify deeply rooted points of leverage by which to repattern settlement systems, understanding that these would appear more often as relational clusters than clearly delineated areas for intervention. These kinds of analyses could intersect with existing methods, such as those which track energy returned on energy invested (EROI) (Hall, Tharakan, Cleveland, Hallock, & Jefferson, 2003), embedded energy (or emergy)[19] implications (Odum, 1988, 2007), human activity in space as captured through big data (Batty, 2013c; Bettencourt, 2014), and urban metabolism (Kennedy et al., 2007; Kennedy et al., 2011). We could experiment with the integration of qualitative and quantitative approaches, juxtaposing studies of meaning against those of infrastructural development and resource flows, exposing the values embedded within forms (see Mehaffy, 2007).

In the least, in Capra's (2002) categorical synthesis of living phenomena, he grants equal attention to processes as to forms, which is a perspective from which we could benefit when planning within urban contexts. Perhaps we temporarily lost sight of the former through the seduction of industrial technology for the built environment (such as steel beams and elevators) (see Ching, Jarzombek, & Vikramaditya, 2011); however, in digitized, globalized settings, we may also be losing grip on the latter (Sassen, 2010). Without the translation of flows into places, or meaning into form, one risks enabling a kind of cultural detachment that strips all character from the public realm. Castells (2006) fears we have, indeed, subsumed the significance of place under "...the exchanges of information, capital, and power that structures the basic processes of societies, economies and states between different localities..." (p. 136). Certainly, we can imagine the urban milieu transcending its physical spaces and taking on a quality of placelessness, especially through the digital realm, which is at once real and intangible, as well as global networks, which are localized in their siting, though international in their consequence. It is not that space and place could become altogether irrelevant, as major infrastructure still requires a physical home and spatial footprint (Castells, 2010a; Rifkin, 2011; West, 2017). When it is said that we are disconnecting from place, this is partly a matter of flow rather than form; our economies, cultures, politics, and ecologies are no longer place bound; they are globalized and may be displacing local identities (Castells, 2010a; Sassen, 2012). From a dwelling perspective, however, we could argue that processes such as industrialization and digitization emerged as part and parcel of the metabolism of human experience within the biosphere and thus can be positioned with respect to our rootedness or boundedness within this planet. Based on the recommendations of Heidegger, Ingold, or Cooke et al., we might resolve to reinvigorate these processes through localized, customized, human-scale expression: "Recovering place means recovering the multiplicity of presences in this landscape" (Sassen, 2010, p. 5).

At the crux of a relational approach to urban planning and design, as this has been developed in science of cities thinking (Batty, 2013a; Portugali, 2000; West, 2017), is the regard for networks as a foundational schematic: Cities are conceived as networks extending in time and space, with individual places as nodes, materializing through the intersection of multiple types of interactions (Castells, 2010b;

[19] *Emergy* "...is the available energy of one kind previously used up directly and indirectly to make a product or service" (Odum, 2007, p. 89).

Sassen, 2012). The Third Industrial Revolution[20] has mobilized around the logic of network organization and is informed by a philosophical acceptance of the interconnection of all things (Rifkin, 2011). Networks also represent the basic organizing pattern of living systems and are a central metaphor incorporated into ecological thinking (Capra, 1996, 2002). Thus, through network analyses, we may achieve some conceptual and methodological unification across the disciplines of ecology (and ecological sustainability), complexity, and urban planning.

Design practice has conventionally engaged in problem solving through the making of *things*, such as ovens to cook food, vehicles to transport people, or homes to protect against the elements. These things are designed as means to an end, though in an object-oriented practice, we could just as easily mistake them for ends in themselves. From a relational perspective, we might instead think about modifying parameters within space and time, innovating within a flexible continuum of viable systems states, organizing patterns of interaction (Batty, 2013a), or rewiring human-environment interactions. More simply, Schrödinger (1967/1944) had intimated that exchange between an organism and its environment, wherein order (or negative entropy) is extracted, is the qualifying property of living (see Portugali, 2016). If life is exchange, and settlements are designed for life, then perhaps settlements are designed for exchange (West, 2017); forms facilitate flows. This does not collapse the relevance of space, materiality, aesthetics, or place-based experience. Instead, each of these could be interpreted with respect to their significance within broader fields of relations. Interpreting settlements as an outcome of their flows, or relational factors, should not encourage a laissez-faire acceptance of circumstantial incident or cumulative effect. Rather, it would lead to a necessary balancing between the material and the ephemeral in analyses and intervention. If we overlook the relationships that exist between forms and processes, we run the risk of governing societies by the demands of our inanimate constructions. Indeed, our cities are almost at this stage, wherein our infrastructural plans drive how we use spaces and places or how we interpret quality of life.

Enhancing lasting social wellbeing and ecological systems integrity is the basic objective of sustainability planning (Gibson, 2006, 2016). To accomplish this, we are stuck with the wicked task of determining how to provide more for this planet's growing populations, with the consumption of fewer natural resources. This was the idea behind Fuller's (1971/1938) concept of ephemeralization—doing more with less through savvy systemic design. Given that our biosphere is one of hard ecological limits, some view this as an illusion of technological development, which has simplified our day-to-day routines, though presumably not without added material footprint.[21] Extending from a relational view of settlement, there may be a trick by which ephemeralization could become feasible, however. By practice, many designers (graphic, industrial, architectural, urban) are materialists. On the other

[20]*Third Industrial Revolution*: This current regime shift represents the implications of information technology on production, operational management, and distribution (Rifkin, 2011).

[21]Personal communication with William Rees, Canadian Society for Ecological Economics Conference, October 4, 2015, Vancouver.

hand, the dwelling perspective and science of cities thinking intimate that settlements are not as much material artefacts, as they are sets of dynamic interactions, organized across hierarchical network formations. From a design practice based on the creation of material things, a materialized world naturally propagates; from a design practice grounded in the coordination of relations, perhaps dematerialized systems could follow.

Emergent Engagement

People inhabit settlements, though, more precisely, we are situated within and co-creating them as natural, emergent, self-organizing, and intentionally constructed socio-ecological systems networks. Key to adopting a relational approach in settlement planning is acceptance that their processes of change can occur quite separately from our visions for idyllic or even functional places of living: They are contingent on multiple, interacting, cross-scale factors, beyond our explicit control or conception. In this light, complexity views of cities have acknowledged the importance of complementing top-down with bottom-up initiatives (Batty & Marshall, 2012; Bettencourt, 2013b; Jacobs, 1961; Portugali, 2012a)—a recommendation that is matched in discussions on innovating for systems transformation and transition, more generally (Loorbach & Shiroyama, 2016; Westley et al., 2011; Westley et al., 2013). From a methodological perspective, there is a more considerable challenge to contend with, however: That is to account for interlinked dynamics occurring across systems scales. For this, some authors have endorsed multilevel governance strategies (Bulkeley & Betsill, 2005; Rotmans & Loorbach, 2009). Regardless of our ability to enable diverse, networked participation in project management or processes of systems change, there may still be incongruity between the scales at which critical issues take effect and those at which we are equipped to track and address them—what resilience scholarship refers to as scale mismatch (Cumming & Norberg, 2008). Once we conceive of systems of settlements as regionalized and globalized networks, it becomes clear why scale mismatch could be an issue in their management.

In planning contexts, the term *process* has been familiarized to refer to collaborative social processes by which decisions are made and projects are developed (Mehaffy, 2008; Portugali, 2011; Rotmans et al., 2000), while design charrettes have slid into place as a proxy for democratic, bottom-up action. Here, I apply the term with an extended meaning (as discussed in the previous section), referring more broadly to the social, economic, political, and ecological dynamics that can be constitutive of systems of settlements. Collaborative innovation processes are embedded within these others. From a dwelling perspective, we could claim they occur as part of our *being* in the world; from a self-organizing city perspective, such would also be the case, as would urban agents be considered planners, in their own right, at a certain scale (Portugali, 2000, 2016). In Portugali's (2000, 2016) self-organizing city, top-down and bottom-up actions bleed together; the distinction between professional and citizen actions is less critical. Arguably, however, at certain scales, the explicit agency behind systems change becomes opaque; neither would every scale of a system be accessible for direct analyses and intervention. According to Bulkeley and Betsill (2005), when it comes to planning for urban sustainability, the appeal of localized action through the implementation of best practices has tended to displace awareness of wider interacting systems processes, and how these take shape, emergently, at a local level. As a methodological philosophy, designing *for* sustainability is not so different from designing *with* emergence, since transition contexts are typically coloured by uncertain, non-linear, cross-scale systems dynamics.

Urbanization was not a product of urban planning, and its history speaks to the inadequacy of the planning profession to serve as a vehicle through which to study and manage its self-organizing, emergent, or coupled socio-ecological processes (Portugali, 2000). Cities would not have been the outcome of a single or linear plan for progress; rather, they represented concurrent and coupled development across varied social, ecological, and technological factors. For example, intensified agricultural production, division of labour, specialty craft-based trades, monumental architecture, science and writing, artistic expression, social stratification, state formation, and foreign trade are thought to have accompanied the first urban revolution in Mesopotamia (Bairoch, 1988; Childe, 1950; de Vries & Goudsblom, 2002; Elmqvist et al., 2013; Portugali, 2000; Redman, 2011; Smith, 2009). Prospects to access labour markets, trade routes, and knowledge networks, maintain individual anonymity, and earn higher wages, while enjoying upward mobility, may have stimulated the second (Angel, 2012). Some authors have identified social reorganization as either the key lever that permitted urbanization or a significant characteristic of it (Elmqvist et al., 2013; Ernston et al., 2010; Redman, 2011; van der Leeuw et al., 2009). Finally, Portugali (2000) has argued that cities are a generative socio-spatial order that have reproduced from within and from each other, as a single, self-evolving system. So too, he argues, are cities merely the elements of urbanization, the latter representing a new mode for the production of society (Portugali, 2000). If we attempt to plan cities as isolated entities, we are effectively condoning the provisions of contemporary urbanism, which are being globally reinforced.

> Cities emerge as one territorial or scalar moment in a trans-urban dynamic. This is however, not the city as a bounded unit, but the city as a complex structure that can articulate a variety of cross-boundary processes and reconstitute them as a partly urban condition. (Sassen, 2010, p. 5)

Complexity theories of cities inquire as to whether cities are, indeed, plannable, given their self-organizing, non-linear, uncertain dynamics, and as systems operating far from equilibrium (Batty & Marshall, 2012; de Roo & Rauws, 2012; Portugali, 2000). The realization that they may not be was notoriously canonized in the work of Rittel and Webber (1973), who characterized planning contexts as open, complex social systems, with the hope of distinguishing the planning profession from engineering and scientific work. Their critique accompanied a turn from Portugali's (2000) first to second culture of cities/planning, wherein quantitative/rationalized approaches, which apply statistical models or claim ability to tame and control the built environment, were being viewed with scepticism (Batty & Marshall, 2012; Jacobs, 1961). They appealed, once planners have solved the easy problems, such as the provision of roads, shelter, infrastructure, schools, and hospitals, there are still stubborn issues to wrestle with, such as enabling social equity or governing amidst social heterogeneity: "In short, they argued that cities were so complex that it was near impossible to trace all the repercussions and impacts of proposed solutions, which often ended up making the original conditions more problematic …" (Batty, 2013a, p. 302).

Rittel and Webber's (1973) article reads like a surrendering of the planning field's early ambitions: There is more to the problem than meets the eye—in fact, we can barely perceive where the problem space begins and ends. In their manuscript, they offered a ten-point description of and guidelines for engaging with wicked dilemmas, which they declared as difficult to define, isolate, or bound in time and space (Batty, 2014). In short, they advised proceeding with caution, given the prospective impacts of decisions, while conceding it may be difficult to prove solutions to be correct, as much as they are suitable or coherent relative to their contexts and purposes. A similar stance is found in post-normal science thinking, which becomes relevant in circumstances wherein decision stakes are high and certainty low (Funtowicz & Ravetz, 2003). When transition management initiatives are embedded within complex systems dynamics, we are caught between the worlds of design and science: impelled to take imminent action, yet without sufficient knowledge to do so with any certain effect. In instances where systems fluctuate beyond precisely predictable states, perhaps our choices for intervention could only ever be coherent with respect to our current understanding of plausible futures (see Lister, 2013/2010).

Settlements display overlapping layers of fixed and variable order. Self-organizing behaviour between citizens may result in spontaneous, temporary activities, like drumming circles on the beach. In contrast, large-scale infrastructure requires controls for consistently safe functioning (Hamdi, 2004; Portugali, 2012b). The rise of smart growth planning in the late twentieth and early twenty-first century signals the significance of governance to certain aspects of settlement development, for example, in the negotiation among competing land-use interests (Curran & Tomalty, 2003). So too have the impacts of uncontained growth, which has plagued cities worldwide, illuminated the drawbacks of uncoordinated change. At the same time, overly stringent municipal policies could impede variation in, or the combination of, socio-ecological features and functions, within space and place. Arguably, the municipality as a political entity is less responsive to nuance than the settlement as a complex adaptive socio-ecological system. There may, however, be opportunity for interplay between centralized and decentralized mechanisms of growth and change (Loorbach & Shiroyama, 2016).

It is apparent that some types of change occur through citizens' direct, personal, intuitive, and adaptive engagement with places and some through the professional application of generalized theories and principles (Alexander, 1964; Portugali, 2012b). In settlement planning, we might consider how to combine one with the other. Attempting to envision and implement comprehensive plans, in their totality, could result in a flattening of socio-ecological heterogeneity, as we have seen in suburban development (Frampton, 1983), neither is it a realistic pursuit: “The idea of the planned city as a knowable utopia is a chimera” (Batty & Marshall, 2012, p. 44). Conversely, while the former is representative of a democratically self-generating city (see Pflieger et al., 2008), there is no guarantee that uncoordinated adaptation would consistently produce sustainable outcomes, which are comprehensive in their response to social needs, optimal in their performance, or considerate of the interaction effects that occur across multiple systems scales (Batty & Marshall, 2012; Berger, 2009; Doxiadis, 1974; McCormick et al., 2013; Ruttonsha, 2017). To facilitate agency within diverse networks and at various levels of settlement (home to neighbourhood to city to metropolitan region to globalized systems of settlements), we face this question:

> …how much structure will be needed before the structure itself inhibits personal freedom, gets in the way of progress, destroys the very system which it is designed to serve, and becomes self-serving? (Hamdi, 2004, p. xviii)

However, the concern with governance structure in settlements is more about type than quantity. Bar-Yam (1992) has explained that networked governance structures are more effective than hierarchical ones, when the behavioural complexity of a collective is greater than that of any one agent or institution that could exercise authority over it. He has indicated how complexity would have initially spiked within agrarian and early industrial societies, through hierarchical control over simple, repetitive behaviours of many individuals, to large-scale effects. In the wake of increased environmental and social complexity, however, hierarchical governance is less viable: The demands evade the capacity of any one institution to respond. Instead, lateral communication between lower-level systems modules gradually takes over as a coordinating mechanism (Bar-Yam, 1992). Moving forward, in Bar-Yam’s estimation, some degree of hierarchical order may persist within complex civilizations. He briefly cites a corporate trend to split management between strategic (hierarchical) and operational (networked) functions. Conceivably, this could be applied in contemporary settlements, as well.

In cities, it is not unheard of for localized diversification to take place on the back of systems that have developed through hierarchical control. As an example, we can run urban farms in our small, private yards, complete with chicken coops and beehives, while still benefiting from potable, piped water and electricity. We can sell and trade goods with our neighbours through informal, online networks (Botsman, 2010), on account of existing telecommunication infrastructure. In these instances, citizens are self-organizing within the boundaries of the modern world to disrupt its underlying order. Focused efforts to create and disseminate innovation in a distributed fashion have also appeared through generative and open-source design initiatives (see Architecture for Humanity, 2012; innonatives.com; Mehaffy, 2008; openstructures.net; Quilley, 2017; Stott, n.d.; Westley et al., 2011). Through these types of initiatives, the economies of scale that render urbanization compelling in the first place still appear—with many people sharing knowledge, resources, and market access—yet, without being tied to a particular place or what economist Paul

Krugman (1991) has referred to as an economic geography (also see Pierson, 2004), thus the placelessness of contemporary, globalized dwelling surfaces. With open-source initiatives, hierarchy does not disappear entirely; rather, the collaborative platforms, themselves, define the rules of the game by which everyone plays. They render creative production accessible to the masses, though always within a specified domain. In selecting the parameters for these forums, their creators exercise agency over user engagement, thus enacting *guided self-organization* (see Helbing, 2013)—which, in essence, is not so different from planning policy. Still, they permit a kind of self-organizing behaviour that could enable greater democratic participation in civic placemaking than public consultation processes, alone, could ever accomplish (Mehaffy, 2008) and at a scale that is indeterminate. Through open-source technologies and processes, we are problem solving across regional and global networks—though oftentimes in response to needs that are small and specific, such as the provision of emergency housing (see Architecture for Humanity, 2012). This is the easier direction in which to travel, when shifting frames between the global and the local—to task international communities with addressing the specific challenges of the few.

Innovating across the multiple globalized scales at which systems of settlements organize would be a considerably more difficult leap, and for which I will not provide any conclusive recommendations, only note briefly why the problem is a wicked one. There is more than one approach by which we could classify scales or levels within systems of settlements. Doxiadis' (1969, 1974) ekistic grid outlined these in accordance with a logarithmic progression, beginning with the individual and ending with the earth-encompassing/universal city. Bretagnolle et al. (2009) listed the levels of urban systems as micro (individual agents and institutions), meso (the geographical area of the city), and macro (the system of cities). Similarly, we could think about levels with respect to the type of municipal change enabled, with micro being indicative of routine operations (i.e. maintenance, renovation, etc.); meso signifying projects that change a neighbourhood or system—such as the development of a waterfront area, a cultural district, or a renewable energy infrastructure; and macro referring to intercity or regional initiatives, such as shared transit lines, climate action plans, or watershed management programmes. At a certain stage, however, it may not be suitable to conceive of and divide the problem space in this way. Some issues will cross levels, drifting or jumping over perceived governance hierarchies. For example, Portugali (2000) has described how the micro level of individual action within a city can have greater impact on the overall city system than intentional municipal planning; Sassen (2010) has discussed how some cities skip the nation-state in their interaction with global systems phenomena and how global city developments can supersede local identities; and Castells (2010b) has contended that megacities are disconnected from the local, altogether (Portugali, 2000). In sustainability planning for systems of settlements, the scales of interest are unbounded. Not to mention, their sources and sites of environmental impacts may vary (Sassen, 2012; Seto et al., 2012).

Thus, we arrive again at the question, what kind of change should we be implementing, and where? Macro-scale social processes may be less conducive to influence through intentional intervention (see Meadows, 1999) and may transform slowly, over a period of generations (Loorbach & Shiroyama, 2016), or too rapidly for us to keep pace (Young et al., 2006). It may be that municipalities do not have access to or control over the critical levers for socio-ecological systems transformations (Loorbach & Shiroyama, 2016): ones wherein we reorient our ways of life, as individuals, communities, and societies (see Dusch, Crilly, & Moultrie, 2010), and with respect to how global phenomena take shape within settlement plans. Still, for some authors, the level of the city is an appropriate point of entry for transition management, as an entity that is conducive to enabling both top-down and bottom-up actions, operates as a node within globally dispersed networks, and engages directly with transnational and global processes (Batty & Marshall, 2012; Loorbach & Shiroyama, 2016; Sassen, 2009, 2010):

> Cities are also sites where each of these trends [globalization, digitization, transnational and translocal dynamics, and legitimation of socio-cultural diversity] interacts with the others in distinct, often complex manners, in a way they do not in just about any other setting. (Sassen, 2010, p. 3)

Thus, settlement systems (and cities) reveal a possible middle ground: to think big and start small (Mui, 2016). Conceptualize the problem at the broadest scale of cultural transformation, while implementing thus-inspired initiatives at a micro level, as settlements move through their natural cycles of retrofitting and growth. Exploit overlapping states of construction and deconstruction as an opportunity to repattern systems. As resilience literature has shown (Holling, 2001), flexibility within a system will be greatest during times of change. As long as settlements are in flux, due to growth pressures, the prospects for developing them on different terms remain open—especially within target growth and transitional areas. In other words, change is the opportunity context for transformation. Resilience literature has shown that complex systems follow natural cycles of fluctuation (Gunderson & Holling, 2002; Holling, 2001; Scheffer, 2009), while innovation thinking has encouraged us to capitalize on these by identifying windows of opportunity, therein, to intervene (Geels & Schot, 2007; Westley et al., 2011; Westley et al., 2013). During these fluctuations, systems may pass through periods of disorder, or loss of order, which permit their restructuring; connections or relationships may be dissolved and new ones generated; resources are reallocated (see Holling, 2001):

> ...in the end it seems that power has less to do with pushing leverage points than it does with strategically, profoundly, madly letting go. (p. 19)

Ultimately, choosing not to intervene, scaling back existing interventions, or *undesigning* could be powerful acts of creative agency.

Conclusion

Systems and complexity thinking advise attuning to interconnections among multiple phenomena (Midgley, 2000), while ecological worldviews claim everything is connected (Capra, 1996, 2002). Processes and outcomes of urbanization, however, confound perspectives on the latter—especially, as these have taken shape within the past 200 years, or so, under the drive of industrialization. How, indeed, could these systems be deemed an integrated part of the same earth systems processes they are simultaneously degrading? The ideal to attain a sustainable future would seem incoherent with the current state of urbanism: "Cities do not fit easily in existing theories about environmental sustainability and global environmental governance" (Sassen, 2012, p. 304). They are a conceptual enigma—emergent from processes of human ecology while compromising their own long-term viability within the biosphere. Whether we embrace or abhor the trend towards urbanization, whether we see potential for a new face of urbanism or prefer to retreat to land-based living, there is no denying that the state of contemporary urban systems and their resonant impact on planetary systems delineate the starting conditions for transition, though the challenges differ in developing and developed nations. So, how should we incorporate this basic understanding into theories about environmental sustainability and global environmental governance?

Conceptual framing is not insignificant to problem-solving processes in systemic design; for example, authors such as Alexander (1964) and Simon (1996/1969) have encouraged experimenting with the focus of design project objectives, to isolate precisely which problem we are seeking to address, and where our interventions could be most effective. In some respects, this is an exercise in boundary definition (Midgley, 2003), though it is also one of perspective shifting. Meadows (1999) has proposed that paradigms or worldviews can be one of the most transformative points of leverage for systems change. In sustainability research, scholars have been assessing how narrative tone and position can en(dis)able action, for example, recognizing that messaging laden in despairing facts about an environment in decline may not inspire desired audience responses (Lynes & Wolfe, 2017; Quilley, 2017). In the field of urban planning, worldviews began to shift in the late twentieth century, as it became apparent that cities are complex adaptive, non-linear systems, operating far from equilibrium, and not subject to absolute control through top-down planning approaches (Batty, 2014; Batty & Marshall, 2012; Jacobs, 1961; Rittel & Webber, 1973). With this, a challenge was ignited, which still underlies science of cities thinking today—to define *the kind of problem a city is* (Jacobs, 1961; Bettencourt, 2013b). This represents an extensive part of the battle for urban planning; another would be to comprehensively conceptualize the relevance of urban systems to sustainability and resilience agendas.

As of late, an international narrative has been emerging, placing cities at the centre of the sustainability problem space (see *Cities as Tension*). This discourse turns on notions that cities are the primary opportunity and challenge for transition (Florida, 2014) and demarcate our fate and future (Sassen, 2012; West, 2017). Though still faint in its formulation, its effect has been to redefine the relationship between cities and sustainability. Proponents of this narrative are not so much advocating for an urban future, as they are recognizing the prevalence of urbanization and its coupling with contemporary ways of life (Sassen, 2012; West, 2017). Through discussion and action around the United Nations' 2015 Sustainable

Development Goals, urban systems have been positioned as both targets for change (see *Cities as Targets*) and the social, economic, and political vehicles by which to mobilize international agendas (see *Cities as Traction*). At the same time, science of cities thinking has hinted at a more significant connection between the intellectual and practical arenas of cities (settlements) and sustainability (resilience) (see *Cities as Embodiment*): The general assertion is that the long-term viability of our socially constructed world will be dependent on the extent to which this can be synchronized with the natural one; urban systems exemplify the historical development trajectory of the former, while complexity thinking can illustrate how this has been generated through interrelated socioeconomic processes (West, 2017). Informed by science of cities methodologies, and linking these with the dwelling perspective, this chapter engages with the problem of framing the relationship between cities (settlements) and sustainability (resilience) while also considering how elucidating *the kind of problem a city is* could reinvigorate approaches to systems change within settlements.

It may be that simple premises could serve to shift perspectives and reorient practices within complex problem domains; this chapter introduces three. The first is intended to suggest that, at their core, both settlement and sustainability, as areas of inquiry and practice, are concerned with the organization of human life within the biosphere. In this way, they are analogous challenges. *(I) Settlements are complex adaptive socio-ecological systems, which together as globalized networks embody the complete range of human-environment interactions, and the complexity that has emerged along with these, over time* (see *Cities: Sustainability*). This implies that human-environment interactions are the heart of settlement systems. It is not that form, space, materiality, and aesthetics are extraneous to matters of urban planning and design; for example, as Jacobs (1961) asserted, urban form ennobles human life. However, what science of cities research has illuminated is that, similar to other complex systems, cities organize in hierarchical network formations, arising from human interactions, as they play out in space over time (Batty, 2013a; Portugali, 2012a; West, 2017). This was also intuitively understood by early leaders in the field (see Doxiadis, 1974; Jacobs, 1961): “For cities, processes are of the essence” (Jacobs, 1961, p. 441).

Though this finding is based in complexity thinking, the means by which we analyse and intervene within systems networks could remain theoretically and methodologically pluralistic. Very generally (and non-exhaustively), quantitative work has been studying universal properties and dynamics that repeat across urban systems, regardless of their history or geography (Batty, 2013a; Bettencourt, 2013a; Portugali, 2012a; West, 2017); qualitative research, and that of urban sociology, have conventionally examined human experiences of place, as well as the localized expression of macro-level, globalized trends (Jacobs, 1961; Portugali, 2011; Sassen, 2010, 2012); urban ecology and resilience scholars have been reintroducing an ecological perspective to urban studies, and expanding an ecology *of* and *for* cities, as complex socio-ecological systems (Elmqvist et al., 2013a; McPhearson et al., 2016); and design-based approaches are well suited for projecting possibilities and pathways for systems change, incorporating cogenerative processes (Mehaffy, 2008).

Simple premises warrant minimalist wording, and there is already a concept that captures the basic intentions of science of cities thinking: the dwelling perspective. This concept originated within phenomenological philosophy, cultural anthropology, and human ecology (Heidegger, 1993/1971, 2001/1971; Ingold, 2000, 2005) and contains undertones of design, planning, sustainability, resilience, complexity, and socio-ecological systems thinking. Its central tenet is this: *(II) The continual unfolding of our socially constructed reality occurs as an extension of our being in the world, enmeshed in a web of meaningful nature/culture relations* (see *Settlements as Dwelling*) (Ingold, 2000; Krell, 1993). This interpretation solidifies the connection between urban planning and the *human-in-ecosystem* perspective found in resilience scholarship (see Cooke et al., 2016; Davidson-Hunt & Berkes, 2003); more importantly, settlement blossoms into dwelling, and dwelling becomes poetic. The dwelling perspective is fundamentally relational and sets us up for an approach to systems analyses that would explore reflexive interconnections between processes and forms, meaning and matter, people and places, actions and spaces, the ephemeral and the concrete, the normative and the positive. More so, its authors have advised that to understand a system—what it is, or what it should be—we can contemplate its many relations. Relations are of the essence, not only metabolically, not only communally, but also symbolically. Their poetry of dwelling is to maintain harmony, or *resonance*, across the interconnected web in which all things are entangled.

Incidentally, there is considerable overlap between the dwelling perspective and science of cities thinking. For example, Heidegger (2001/1971), Ingold (2000, 2005), and Cooke et al.'s (2016) articulations of the concept represent (**ai**) a plea to enhance our tacit engagement with inhabited environments, to balance overly cognitive approaches to transition (Cooke et al., 2016; Ingold, 2000); (**bi**) aspirations to reveal the authentic essence of self, community, world, and self in community/world, as a foundation for creative production (Heidegger, 2001/1971; Ingold, 2000); and (**ci**) a proposition that regionalized clusters of interconnected places emerge through routine life processes, occurring in space over time (Ingold, 2000). In science of cities work, there has been similar interest to unravel (**aii**) the coupling among social, ecological, and technological phenomena (Elmqvist et al., 2013a; McPhearson et al., 2016); (**bii**) the fundamental nature and function of cities (Bettencourt, 2013b; West, 2017); and (**cii**) how scale-/network-based interactions are embodied in urban places (Batty, 2013a; Castells, 2010a; Sassen, 2012). Moreover, both sets of authors have touched on the necessity to study (4) the multi-scale profiles of human systems (Cooke et al., 2016; Elmqvist et al., 2013a; Heidegger, 2001/1971; Ingold, 2000; Portugali, 2012a; Sassen, 2012). Through globalized networks of many varieties, our patterns of dwelling exhibit expansive footprints. As a conceptual lens, then, dwelling is both local and global in scope—the processes of our human ecology enacted at multiple scales. According to the dwelling perspective, we can connect with the macro through the micro, by remaining accountable to all of our relations, as they appear within our own lifeworld (Cooke et al., 2016; Heidegger, 2001/1971; Ingold, 2000).

A third premise could be drawn out from the second, and one which could eventually compel a complete inversion of the problem space. Yet to be comprehensively articulated is how a science of settlement could connect to or extrapolate from a science of human life within the biosphere; neither is it intuitive to branch out in this way, though we find a touchstone for doing so in the thinking of biologist and cybernetic theorist Humberto Maturana (2016). He has offered another framing of the relationship between settlement and sustainability, by positing that all transition agendas could be distilled to the simple question, *how do we want to live together?* This positioning is broad yet pithy. In spirit, it prompts pluralistic responses, without specifying the details. It could lead to classic design-based initiatives, though it also evokes a need for interdisciplinary and transdisciplinary work, which could compare human life ways against the constructed systems that support them. Really, these are two sides of the same problem space. This is apparent if we consider Maturana's query to be an inversion of Schrödinger's (1967/1944) *what is life?* and Capra's *what are the defining characteristics of living systems/social reality?* (2002, p. 3), or a simile of Mau's (2010) *how do we design for the welfare of all life?* Taken together, these questions bat between analyses and action, stretching to interpret and cope with the complexity of our planet's living systems, though each from a slightly different angle. Schrödinger's main proposition was that organisms maintain a state of living, or produce negative entropy, through ongoing exchanges with their environments. Capra's extension has bridged science with design:

> In the future, this strict division [between material and social structures] will no longer be possible, because the key challenge of this new century—for social scientists, natural scientists and everyone else—will be to build ecologically sustainable communities, designed in such a way that their technologies and social institutions—their material and social structures—do not interfere with nature's inherent ability to sustain life. (Capra, 2002)

In systemic design, Mau's team tackled the inquiry as part of their Massive Change project, which explored the capacity of design to enable positive action in light of pressing global challenges (Mau, 2010; Mau et al., 2004). There are many approaches by which we could respond to these comparable and foundationally orienting questions, whether through empirical, normative, or creative methodologies. They have clear affiliations with complexity science, though could also be associated with the work of ancient Greek philosophers, such as Aristotle. In addition, through these questions, we gain some sense of how a programme of research and practice, for transition within settlements, will flip, recursively, between structure and substance. To respond to the challenge of managing human settlements for growing populations with rigour and validity, eventually, we must assess the meaning of human welfare and ecosystems integrity, as well as the conditions that facilitate or constrain either or both. Thus, the third premise is this: *(III) Characterization of dwelling calls for rich deconstruction and classification of the content, composition, quality, quantity, catalysts, and extent of human-environment interactions* (see *Systems Dynamics as a Basis for Place*).

In systemic design communities, we have seen two intersecting trends, occurring intermittently, namely, in the late half of the twentieth century and onwards. In the first, we have sought to legitimize design as a unique way of knowing, a procedural practice, a social process embedded in discourse, and a discipline as rigorous as any science (Cross, 2007; Margolin, 2002; Nelson & Stolterman, 2012; Simon, 1996/1969); in the second, we have become increasingly concerned and involved with environmental and social issues (Fuller, 1981; Irwin, 2015; Margolin, 2002; Mau, 2010; Papanek, 1971; Tonkinwise, 2015). These trends are brought to a head within the context of cities, as the challenges we confront within urban systems become increasingly complex, high stake, and broad in their impact and implications. With this in mind, it would be timely to review the questions, methodologies, and goals on which our work is based. While complexity theories of cities tell us that urban systems are not conducive to control through planning processes, we could augment this argument by suggesting they cannot be evaluated and managed exclusively through urban planning and design. Through a socio-ecological science of settlement, we could integrate descriptive with prescriptive methodologies, to examine settlement systems on analytical terms such that we might rebuild them on practical ones. This could expand urban planning and design frameworks with reference to their socio-ecological contexts, informed by the observation of human-environment interactions; note the quintessential patterns that emerge through the interrelation of multiple systems phenomena; focus on network structures and dynamics as the basis of study and sites for innovation; and distribute action for transition among a range of stakeholders, across multiple scales. Ground this with the dwelling perspective, and we may arrive at an approach to systemic design that is critically and intuitively responsive, scientific and poetic.

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Part III
Method and Practice

Visualizing Complex Design: The Evolution of Gigamaps

Birger Sevaldson

Abstract Around 2005 the concept of Systems Oriented Design (SOD) was slowly emerging. This happened organically through experimental design practice and education-based R&D at the Oslo School of Architecture and Design. Centrally in SOD is Gigamapping, a technique to map out, contextualize, and relate complex systems, their environment and bigger landscape, their current state, as well as preferred future states. The role of the Gigamap is constantly developing. This process has partly been a planned research process and partly a process of discovery and conceptualization through research by design. This chapter recapitulates and analyses this long-term process of developing the concept of the Gigamap. It goes through and discusses the sources and inspirations, the framing and methodology, and the concepts that were described until recently. Some of these concepts emerged as tacit knowledge made explicit; others were systematically planned and developed over time.

The paper concludes by introducing a new sense sharing model for visual collaboration.

Introduction

Systems Oriented Design (SOD) emerged organically around 2005 at the Oslo School of Architecture and Design (AHO) through experimenting with design practice and new modes of education. A primary methodology in SOD is known as Gigamapping, a technique for collaborating groups to map, contextualize, and relate complex systems, revealing their environment and landscapes (of interaction), their current states, as well as preferred future states. Gigamapping has been a central tool for co-inquiry where experts, users, and other stakeholders are brought together and are immersed in dialogue across their specialized cultures and terminologies.

This chapter recapitulates and analyses this long-term process of developing the concept of the Gigamap. It discusses the sources and inspirations, the framing, and

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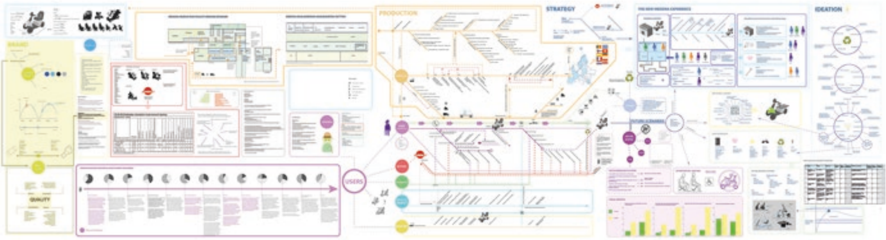

Fig. 1 A Gigamap of a Norwegian manufacturing company (Medema). The Gigamap can express models of relations and interconnectedness to timelines, floor plans, statistics, and illustrations. (Julian Guribye and Christian von Hanno, AHO 2011)

the methodology. The dialogic aspects of Gigamapping processes are examined, and the related concept of sense sharing, describing one of the main benefits of Gigamapping, is proposed (Fig. 1).

Gigamapping has been established as an important tool in Systems Oriented Design (SOD) throughout recent years, especially at AHO, and has spread to other universities and firms (Aguirre & Paulsen, 2014; Aguirre-Ulloa & Paulsen, 2017; Hensel & Sørensen, 2014; Jones & Bowes, 2016; Jones, Shakdher, & Singh, 2017; Sevaldson, 2011, 2013; Singh, 2013). Gigamaps have been developed further into more systemic variations, for example, the synthesis maps taught at OCAD University (Jones & Bowes, 2016). The use of Gigamaps has started to spread to public organizations (Bogen, Jensen, LeBlanc, & Tveit, 2014) and private companies[1]. While these processes were seen as time consuming and cumbersome in the beginning, there is a growing understanding of its usefulness and the benefit for deep systemic developments (Fig. 2).

Throughout this period, the role of Gigamapping has been discussed and developed. From the start, the role of the Gigamap was to be an inclusive and undogmatic approach to large-scale system mapping. Its main purpose was to help designers get a grip on complexity in larger-scale projects. Through the map, one could harness the design process and the practice of design to become a strong mode of inquiry for understanding systems as well as designing them.

The Gigamap is a tool for *design inquiry* as defined by Nelson and Stolterman (2012). Design inquiry is a special form of knowledge production at the same level as scientific and artistic inquiry. Design is concerned with different kinds of knowledges, including the sciences and arts, but what sets it apart is its focus on "what ought to be" rather than describing, analysing, and understanding "what is." When design as knowledge production is conducted systematically and it is discussed critically and disseminated academically, it is called research by design (or research through design) (Birger Sevaldson, 2010). We consider Gigamaps as devices for design inquiry rather than analytical tool like those used in systems engineering or in hard systems models. Therefore, the maps are seen as design artefacts, a con-

[1] Most notably is the Norwegian design consultancy Halogen (www.halogen.no)

Fig. 2 A leader group in a private company participating in a Gigamapping workshop. Typically, there are multiple actors involved in working on the map and temporarily engaged in side conversations. (Photo Birger Sevaldson, 2014)

struction similar to the final design product, service, interaction, social process, urban plan, or building that might be its final design output. This approach is theoretically grounded in constructivist learning (Hein, 1991) and draws on constructivism as influenced by Piaget, Dewey, and Vygotsky. Developing the Gigamap through design iterations is a strong way of refining the insights into the complexity of the systems at hand and to cut across scales from myriads of details to large-scale patterns.

Design on the Move

Design is moving into evermore complex fields and advanced forms of application (Jones & VanPatter, 2009). Systems Oriented Design and the use of Gigamapping are very useful in this dynamic situation, where so-called very rapid learning processes are central (Sevaldson, 2013a). This migration of design is driven by a fourfold action:

1. Design is enlarging its scope through specializations like service design, interaction design, and social design. Richard Buchanan described this higher level as the fourth order of design:

> It refers to all the design initiatives that are particularly responsive to the goals of democracy. It may deal with the provision of human rights, and fundamental freedoms (such as access to food, shelter, health care, and education) and, more in general, with the transition towards a more resilient, fair and sustainable society. (Buchanan, 1992)

Tony Golsby-Smith writes in his interpretation of Buchanan's four orders:

> …. Widening of the influence of design outwards into the surrounding medium – the life of organizations in the modern world, or of governments and communities. (Golsby-Smith, 1996)

This well describes the situation of how and where design is moving.

2. The notion of design has become increasingly blurred. This started long ago with Herbert Simon's proposal for a definition of design:

> Everyone designs who devises courses of action aimed at changing existing situations into preferred ones…Design so construed, is the core of all professional training; it is the principal mark that distinguishes the professions from sciences. Schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design. (Simon, 1969)

Interesting in this is that there is a growing realization that designerly ways of thinking partly are at play in many practical situations and that some designerly approaches might be useful in a much more general sense than just for the design professions. On the other hand, this definition erases the boundaries of design to a degree that makes it absurd and nebulous instead of pinpointing what is the essence of the design professionally speaking.

3. Following the above there has been a spread of ideas from the design professions into the business world and other professions. Perhaps the most popular manifestation now is the diffusion of Design Thinking into many fields. Initially Design Thinking was defined by people including Rowe, Buchanan, Goldschmidt, and Lawson (Buchanan, 1992; Goldschmidt, 1994; Lawson, 2006; Rowe, 1991), influenced by Schön's concept of the reflective practitioner (Schön, 1982). Later it was brought to the business world by Boland and Collopy (2004), Roger Martin (2009), Brown and Katz (2009).
4. Globalization and the need for sustainability, as well as the rapid development of new technologies and cultural changes, forces design to become better at understanding and interpreting causes and effects, trends and dynamics, and requirements and parameters influencing the design process. Simple object-oriented perspectives[2] that ignore interrelations and networks of connections as well as contexts and environments simply are insufficient. Golsby-Smith puts it this way:

> Just as the product is not only a thing, but exists within a series of connected processes, so these processes do not live in a vacuum, but move through a field of less tangible factors such as values, beliefs and the wider context of other contingent processes.

The common denominator for this fourfold development is that design has become much more complex and diversified, as well as interconnected beyond its professional boundaries. This has significant implications for design methodology

[2] The term object-oriented is used here in a generic sense. The object is any entity from physical object to service, incident, and event. Designers traditionally tend to have their attention geared towards such design entities or objects without questioning their boundaries or relational webs.

and perspectives. There is a need for the diverse fields of design to better understand its conditions, its entanglements, and the assumed and counterintuitive effects of its activities.

Systems and Design

Systems thinking is the science of interconnectedness. Design could be described as the science and practice of "what might be." As such, it moves into evermore complex fields and faces increasingly complex challenges. Therefore rejuvenating its relation to the science of interconnectedness (systems sciences and systems thinking) is needed.

Systems approaches in design are not new, but they have failed to create and hold a wide-reaching impact on the field (Collopy, 2009). Among the notable precedents, we find Christopher Alexander, Bela Banathy, Russell Ackoff, and Horst Rittel (Ackoff & Sheldon, 2003; Alexander, 1964; Banathy, 1997; Protzen & Harris, 2010).[3] Typical for these authors is that they describe and discuss ways of implementing systems approaches to design, but they fail to develop and demonstrate a substantial systemic design practice. In most of the attempts to introduce systems thinking to design, the perspectives in the outset alien to design practice have been imported into the field of design as additions. This means they have not gone through an adaptation process so that it made sense and was convenient or even possible for designers to change their practice. The imported methods were disturbing to the psychology of the design process, which is imaginative, visual, and judgement-based, (Arnheim, 1969; Gedenryd, 1998; Schön, 1982) and where creative flow incubation and illumination is important (Csikszentmihalyi, 1996). This dissonance between the imported systems approaches and the design process was notably debated by Collopy (2009).

The imported perspectives tend to explain design through something other than its self, e.g. as cybernetic feedback circles or "circularities" (Glanville, 2014) or design as conversation (Pangaro, 2016). These images of design are valuable not as fulfilling explanations but as contributions to the many descriptions of design, a field that is too diverse and varied to be captured in simple definitions. While such descriptions are useful, they fail to talk about the inner nature of design as a specific activity based on visual thinking.

The emerging field of systemic design has grown from Systems Oriented Design into a pluralistic, inclusionary, and pragmatic discourse community. With no canon or disciplinary gatekeeping, differing approaches exist together, some more theoretical, others more derived and developed from practice.

The traditional systems theories and their application in design have slightly faded in the light of the designerly perspective in systemic design. Not all of them

[3] Ackoff was studying architecture. Rittel was a professor at the Ulm School of Design. Banathy, at Saybrook for some time, was connected to design methodology movements.

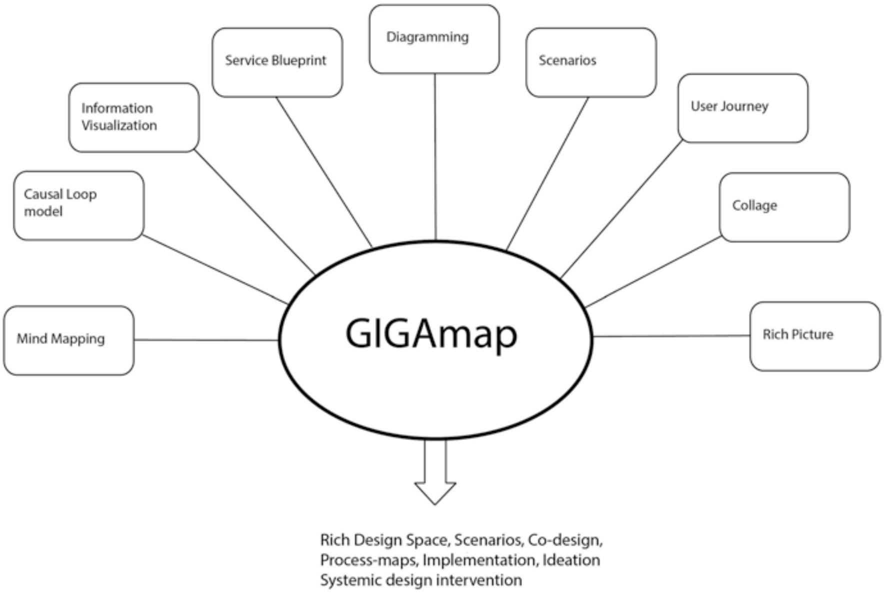

Fig. 3 The Gigamap earns its name not only from the number of elements that it should contain but also from the numerous representative modes and models it might integrate (Sevaldson, 2013)

are equally useful for design action. Nevertheless, they are still forming an important backdrop and inspiration for Systems Oriented Design. Soft systems methodology (Checkland & Poulter, 2006) in particular, with its visual technique of the Rich Picture and its orientation towards intervention, change, and action, and the methodology of action research adopted by design and systems research (Ison, 2008; Swann, 1999) have been important inspirations and anchoring points. At the same time, we were aware of the limitations and advantages of harder systems models and therefore adopted a pragmatic and eclectic view on the existing systems approaches. This position is grounded in Critical Systems Thinking (Midgley, 2000; Ulrich, 1983). This implied the inclusion and integration of various systems models as well as different types of other information, like texts and images, collages, diagrams, narratives, cartoons, storyboards, service blueprints, etc. into the Gigamaps (Fig. 3).

Design often considers what we call composed perspectives. This means that we are navigating complexities that are crossing technological, biological, and social realms. Design deals with both deterministic and unpredictable systems—framed and tamed ones as well as wild and wicked ones (Rittel & Webber, 1973). This implies that we might find ourselves at both soft and hard ends of the systems approaches, as well as in qualitative realms that are not well handled by the traditional systems models. In fact, Systems Oriented Design is more oriented towards the qualitative and visual than most other approaches and therefore leans on and benefits from these core competences of design (Sevaldson, 2014).

Interdisciplines

Design culture suggests design practice exists more on the soft, ambiguous, and fuzzy side of the spectrum of innovation and development, than on the harder technology-driven side, which traditionally is handled by engineers. In reality, designers in teams more often than not work with technology and sociotechnical systems. Technological systems at large are "hard" and deterministic. We compensate for our lack of grips with hard systems through interdisciplinary collaborations with systems engineers, process and computer scientists, and other technical experts. This is not limited to the hard end of the spectrum, but it also expands to fields involving other experts, like social scientists.

In addition, we find ourselves working in interdisciplinary networks of users and other stakeholders representing different cultures and different fields. These might be sorted within a spectrum between "hard and soft" process and culture, but there are likely to be enormous gaps and variations across any network of stakeholders. These gaps and variations can be bridged by systemic design methodology such as Gigamapping. Bridging means not necessarily a common view rather than establishing empathy where diverging views are not necessarily reconciled but understood.

The complexity of the institutional, organizational, and social networks involved in design activities is increasing at pace with the growing challenges to design. Information and knowledge exchange is critical to the bridging process in the complex social constructions that make up a design project. This is not limited to the exchange of facts and data. Data is interpreted into information and constructed into knowledge, creating the basis for particular worldviews and wisdom[4] (Ackoff, 1989). The different types of expertise and interests represented and affected by a design project touch on widely different worldviews. A synchronization of perspectives and worldviews is called for, and this demand is not resolved by information exchange. We need high-level collaboration methods. Codesign methodology based on shared visualization through Gigamapping has proven to be a highly efficient tool for sharing worldviews and detailed perspectives across disciplines.

In such situations, Gigamaps function as bridging tools for dialogues across cultures. It is hence important that the Gigamapping process does not submit to any predefined systemic model nor creates its own resolved modelling of systems. The Gigamap's role is instead to be the in-between, the infill, and the multiple bridging system between expertise, knowledges, models, and fields.[5] Gigamaps are not models as such. They can embrace and contain particular systems models and relate those to other types of information. Hence, they are slightly unique for each situation and case and need to be designed accordingly for each instance.

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[4] I am referring here to the DIKW pyramid: data, information, knowledge, wisdom (Ackoff, 1989).

[5] This includes other stakeholders, like users or inhabitants in communities who are treated as experts.

In particular, tension between models and worldviews, expertise and stakeholder, can be turned into productive richness where the Gigamap is the arena of co-existence.

A Knowledge Framework

Gigamapping has been extensively developed previously by the author (Sevaldson, 2011) and has been presented and taught at conferences and workshops. It is a multipurpose and multilayered visualization with multiple uses and intentionalities and corresponding design actions. Among them, we find:

- Grasping complexity: the system, its sub- and suprasystems, its environment, and its landscape
- Designing, sharing, aligning, and criticizing an image of a complex situation
- Understanding and sharing problem fields (problematiques)
- Modulating relevance and prioritizing importance
- Critiquing and adjusting boundaries
- Moving seamlessly between the descriptive and generative

The framework of knowledge (epistemology) for Gigamapping is based on pragmatism, a way of knowing and working we refer to as *praxiology*. The term praxiology was first used by Cross (Cross, 1999) in the field of design as a systematized accumulation of practice-generated skills, experiences, and knowledge. Though Cross does not define praxiology precisely, it is implicit in the way the term is employed. Much earlier, Gasparski developed a model of praxiology in design as a systemic approach (Gasparski, 1979). While methodology seeks generic description of how to proceed in a design process, praxiology is registering, describing, and critiquing particular situations in practice. The aim of praxiology is to reach a level of "wisdom" and experience where the practitioner can combine their resources with experience, judgement, and intuition. This also includes motoric skills and motoric memory, depending on the practice[6]. This is closely related to the concept of adaptive expertise. The Dreyfus skill acquisition model emphasizes the ability of experts to act on intuition (Dreyfus & Dreyfus, 1980) which they propose as the hallmark of expertise (Fig. 4).

Praxiology is the systematic and continuous study, analysis and pragmatic development of skills, explicit and tacit knowledge, approaches, libraries of concepts, technical methods, conventions, and heuristics and strategies in advanced practices. As a knowledge framework, praxiology leads towards an understanding of design as *practice* rather than through theory and methods. For this the term and concept of praxiology seem adequate. Strictly speaking, methodology is the systematic analy-

[6] For example, for designers the motor skill of visualizing through drawing is important in Gigamapping. It aids the sketcher in the internalization of large amounts of information as well as participants viewing the process.

Novice	Little context and situation awareness. Sticks to basic rules provided by boss.
Advanced Beginner	Limited context and situation awareness. Little ability to prioritise. Knows and follows basic rules. Follows standards and routines given by boss.
Competent	Increased context and situation awareness. Able to cope with complexity. Can see long-term goals. Knows and follows rules, standards and routines. Follows guidelines given by boss.
Proficient	Holistic perspectives and ability to prioritise Can see deviations from normal patterns. Less dependent on rules, standards and routines. Follows generic guidelines and principles, e.g. best practice.
Expert	No longer dependent on generic guidelines and principles. Deep tacit understanding of situations. Follows intuition based on long experience. Adaptive expertise, able to adapt to new situations.

Fig. 4 Five levels of expertise. Interpretation by the author based on the Dreyfus skill acquisition model

ses of methods and strategies in doing (scientific) studies. Methodology is also the systematic relationship of methods to a problematic context. It's how we know which methods to apply. The aim of methodology is to produce prescription of how to go about a problem. It is based on repetitiveness. Methodology in this sense is not very easily applicable to design practice where context variations require adaptations based on judgement and experience. In addition, design problems are typically processes of negotiation between large numbers of requirements, parameters, and variables. Such networks of interlinked problems, which change dynamically according to real-time forces playing out in the midst of the planning process, are described as wicked problems (Rittel & Webber, 1973).

Prescribed methods are only partly useful and could even show to be counterproductive. Because of this nature of the design profession, design methodology has been in a constant crisis and continuously critiqued and developed (Broadbent, 2003; Cross, 1984; Gedenryd, 1998). In contrast, praxiology as understood in this context does not seek prescriptions but is more concerned with collecting samples, experiences, and demonstrations to help in guiding the development of judgement, context awareness, intuition, and adaptive expertise (Kolko, 2010; Smith, Ford, & Kozlowski, 1997).

In Systems Oriented Design over the last 10 years, a substantial foundation for praxiology has been developed (Birger Sevaldson, 2009) with a recent example being the *Library of Systemic Relations* (Birger Sevaldson, 2016). This is a practice-based systematization of the characteristics found in relations when working with Gigamaps. When turning the attention from the object to their interconnectedness, working with real-world systems and without the restraints from orthodox systems models, it became clear that the common use of systems relations in those models was insuffi-

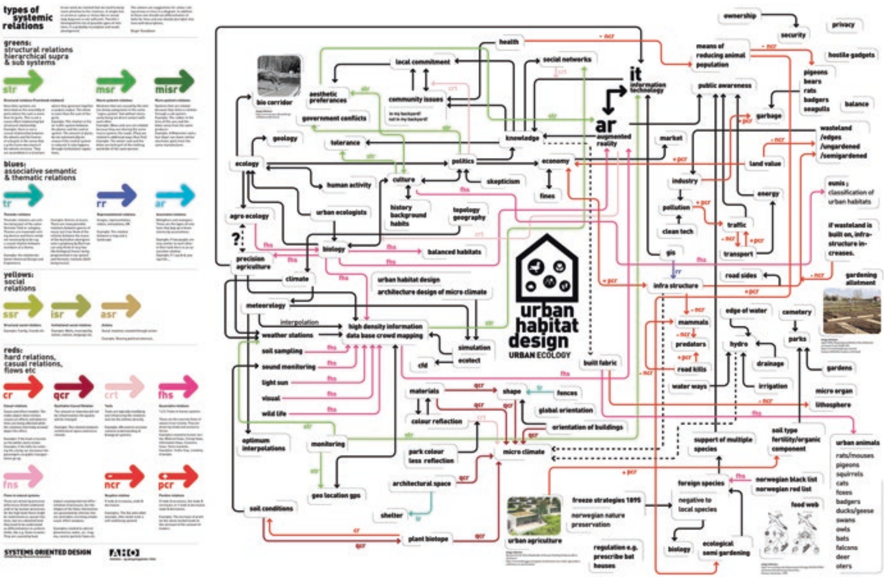

Fig. 5 A Gigamap with heavy emphasis on the relations. The relations are colour-coded according to the suggestions from the "Library of Systemic Relations" web page. The library is part of the Gigamapping praxiology and not seen as a method of rigid classification (Young Eun Choi, Birger Sevaldson, AHO 2013)

cient. The format of the Gigamap, allowing and encouraging the mix of differing categories, graphic expressions, media, and mixed methods approach, results in a very resilient and adaptive mapping model because they are design constructs and not obliged to follow predefined rules. This robustness allows unlimited types of information to be mapped out and networked within the same image. Turning attention from objects to relations is a central feature of systems thinking. Describing the relations in detail was a natural consequence, and from that, the Library of Systemic Relations was built. We regard it a library and not a typology, to emphasize its openness and incompleteness, so that it could be developed further. It is also not meant to establish a convention, but it is meant to provide a repertoire of variations (Fig. 5).

Myriadic Quality of Gigamaps

While mapping in general is a way of ordering and simplifying issues, so to say "tame" the problems, Gigamapping is not a problem-taming methodology. Wicked problems are not resolved through "taming" and framing. Gigamaps try to grasp, embrace, and mirror the complexity and wickedness of real-life networks of interrelated problems (problematiques). Hence they are not resolved logically nor is the designerly urge for order allowed to take over too much and hence bias the interpretation of reality.

This can be seen as the *myriadic quality* of the Gigamap. One cannot represent the lived reality of rich experiences or truly appreciate complexity with a reductive and simplified expression. The myriadic quality of the Gigamap communicates other qualitative levels than a simple registration of numerous entities and their relations. Anderson (1972) demonstrated that scientific laws that are valid in simplified situations are not necessarily valid when things pile up in large quantities. His treatise on the limitations of reductionism in *More Is Different* (Anderson, 1972) was a substantial contribution to the understanding of emergent phenomena. Gigamaps break the restraints of formalized systems methodologies, such as systems dynamics modelling, which can be costly and reductive with the necessity for rigour and computational simulation. Gigamaps are therefore not a replacement of other systems models or approaches but an addition to the field of design methodology.

Managing Map Complexity

Gigamaps are intentionally vague and unresolved. The simplification needed for clarity would unavoidably lead to reductionism and singular interpretations of the map. This does not exclude simplification and singling out particularities of the map for operational and tactical reasons. This is often done on separate documents like so-called minimaps or lists of strategical actions. The ZIP analysis, a regular tool in the SOD toolbox, is helping this derivation of strategies, actions, ideas, and interventions. It is a simple method for developing Gigamaps and to find potential areas for interventions and innovations. ZIP analysis has been described before so we will only quickly recap it here (Romm, Paulsen, & Sevaldson, 2014; Sevaldson, 2013b).

ZIP stands for Zoom, Innovation, Potential. The analyses are conducted by marking the Gigamap with the three points where needed. One can do this while developing the map or in separate analysing sessions where one would investigate the map to search for these points.

Z: Zoom is used to mark areas or points in the map that need more research. It is a reminder that one lacks information and is an initiator to make additional maps for zooming into the marked area.

P: P stands for potential, problem, or problematique. If there is an obvious problem, this is always a potential for improvement. There could be big potentials in things that work very fine. One could learn from them and use the principles on other similar situations. We might also think of P-points in the sense of leverage points for intervention (Meadows, 1999).

I: I stands for idea, innovation, or intervention. If one gets a new idea or a solution to a problem or one can link things in new ways by creating new relations, these are I-points. Interventions are not necessarily new and innovative, but they are actions that tweak and change the system, e.g. resolving a bottleneck in the system (Fig. 6).

While the extracted documents from the ZIP analyses can be precise and well defined, the Gigamap itself should be allowed to maintain its vagueness and unre-

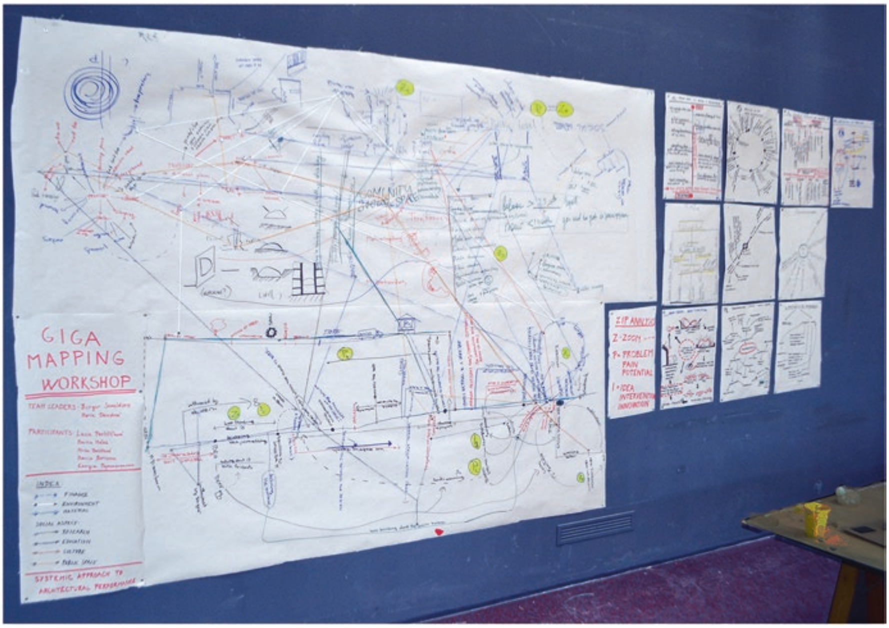

Fig. 6 Gigamap with additional minimaps and texts that describe potential actions and interventions. The yellow dots depict the ZIP analyses (*Lucie Pavlistikova, Martin Malek, Mirka Baklikova, Mariia Borisova, Georgia Papasozomenou, 2016)*

solvedness, its unfinishedness, and "myriadic quality," so that it is maintained as a source for alternative design proposals, criticality, and reflections throughout the design process.

Gigamaps represent composite perspectives. This means that the codesigners do not necessarily settle on a shared perspective, but they share an understanding of the multiple perspectives that are constantly and dynamically at play in the process. This helps in developing the needed empathy and mutual agency for complex codesign projects to work. In design, we are navigating complexities that are crossing technological, biological, and social realms. This position is argued for in Critical Systems Thinking (Midgley, 2000; Ulrich, 1983) where an appraisal of fact-based reality, human and social values, and multiple system boundaries is taken into account. The Gigamap earns its name not from the numbers of entities and relations, which may range beyond a few hundred, but from the potential of myriads of connections, meanings, interpretations, and layerings that are implicit in the mapping.

We can summarize the following:

- Gigamaps are an inclusive and undogmatic approach to large-scale mapping.
- Hard framing and imposed rules are counterproductive and limiting.
- They are a tool for *design inquiry*.
- The maps are design artefacts developed through design iterations.
- They span from myriads of details to large-scale patterns.

Ruptures

Ruptures are a common problematic phenomenon when groups of people collaborate to deal with high degrees of complexity. Ruptures take place in the form of information or communication breakdowns as well as misaligned perspectives between people involved in, and influenced by, a project. Such breakdowns commonly occur between people in the system and between systemic and cultural perspectives. Ruptures can appear because of structural reasons (the systems information structure is insufficient) or over time (things get lost in the process) or by general misconception of the implications.

The most common error causing misinterpretations and communication ruptures is that the models representing the problem or task are oversimplified. For example, a company can be conceived according to its organization chart, which is more an organizational abstraction than a model reflecting the real, interpersonal dynamics of the organization. These erroneous models could be caused by ignorance or by biases, such as to get a sale quickly and cope with the problems later. Ruptures can result from many different interactions:

- Lack of ability to cope with information overload causes decisions based on short memory.
- Clients and stakeholders are not understood well enough.
- Dis-alignment within the organizations causes unaligned perspectives.
- To narrow or wrongly framed horizon.
- Implementation problems that were not foreseen.
- Different conceptions of system shape, structure, extent, connectivity.
- Different sensitivities towards the system.

Sooner or later ruptures will surface. Typically issues will emerge in transitions, such as when moving from planning to implementation. We might say a rupture results from a mismatch between the models one operates accordingly and the reality these models represent. Another example are the well-known problems accumulating over generations of software development where there is a rupture between older and new generations of software developers, causing loss of overview, or where new features are added that might conflict with earlier intensions manifested in the software architecture. The ZIP analysis in Gigamapping can assist in unearthing potential ruptures in the context reflected in mapping.

Stakeholders and Actors

Ruptures always appear between actors in the project. They are a natural part of our co-existence. In addition they are not necessarily negative but might be moment for creative tension. The different experts making up a development team have different perspectives, priorities, and worldviews. It is unavoidable that misunderstandings

	Designer	Design team	Client	Experts	Users	Society	Agency
Designer	A						B
Design team	C						
Client	D				E	F	
Experts							
Users					G		
Society							
Agency							H

Fig. 7 A matrix with the simplified stakeholder and actor list can be used to search down potential ruptures before they appear

and conflicts of interest appear. However these ruptures can be turned into leaps of innovation for the team. A list of actors or matrix of stakeholders in a systemic design project can become quite lengthy; Fig. 7 presents a notional set that limits it to consist of the individual designers, the design team, the client, experts, users, society, and agency (stakeholders who cannot represent themselves, e.g. elderly, future generations, and nature). We can map out the relations between this simplified set of actors in a matrix to determine where the most critical ruptures might emerge among relations.

The letters in the matrix indicate potential ruptures by locating and assessing relationships. Interestingly, ruptures can appear even within the worldview of an individual designer, when a composed picture of a situation contains unresolved contradictions caused by insufficient information or incomplete pictures of the situation (**A**). This is probably a very common rupture. Traditional design educations did not teach designers to systemically investigate the design problems and the new problems they could cause by solving singular problems. Other ruptures might appear between:

(**B**)—Designer and agency, e.g. the designer is not able to represent absent interests well enough.

(**C**)—Designer and the design team. The team is not synchronized in their worldview.

(**D**)—Designer and client. The intentions of an architect might be different from those of a property developer.

(**E**)—Client and users. Clients might have a lesser understanding of the users or stakeholders they involve.

(**F**)—Client and society. Property developers are regularly in conflict with general preservation interests.

(**G**)—Users and users. Different user groups do not necessarily share worldviews and interests.

(**H**)—Agency and agency. Representing elderly or children might be in conflict with taking agency for other living beings.

A central intention in SOD is to act proactively on complexity. Shying away from potential difficulties to resolve them when they eventually emerge is a poor strategy for knowledge production and design. It is both expensive and delaying, and the window for responding in a good way is already closing. Imagining possible problems in advance is a better strategy. Even quick analyses like indicated in the matrix above would help searching for potential trouble and help to avoid gaps in information flow and to maintain ownership. This does obviously not guarantee a smooth process, but it reduces the number of ruptures and trains the awareness and readiness for action when unexpected issues emerge.

One function of the Gigamap practice is to help bridge relationships around possible ruptures and to find, *if possible,* synergetic or balanced solutions. We cannot solve all conflicts through design and communication, but such approaches and perspectives help at negotiating ruptures and conflicts better.

The Gigamap as Bridging Device

Many of the mentioned types of ruptures can be bridged before they develop into serious problems. Bridging does not mean to agree on the same worldviews. It rather means to create the needed mutual co-understanding and empathy for diverse positions. Empathy based on knowledge of other perspectives is the precondition for dialogue and the prevention of destructive conflicts. Negotiation to reach balanced solution is dependent on such empathy.

The Gigamap has proven to be an ultimate bridging device. It is easy learned and easy to apply. Especially within groups of collaborators, the bridging and synchronizing effect is remarkable. We have run a large number of workshops with business leaders and other groups where they report on this effect. Even for people who have worked together for years and who should be fairly synchronized, hidden ruptures are unearthed and addressed (Fig. 8).

Fig. 8 A quick draft, describing the typical project timeline for the TPG management consultancy

In 2011 AHO worked with a leadership development consultancy to include Gigamapping, especially in the form of timelines, in their methods and workshops. This work was done through the involvement in management consulting activities by AHO staff over a long period of time (2012–2016). This was centred around a collaboration with the management and leadership development consultancy TPG (The Performance Group).[7] The collaboration also included student projects and internships where methods and perspectives were developed further. A particular useful output was the booklet "Complexity and other Beasts" addressing practical issues (praxiology) when dealing with complex issues in group work (Skjelten, 2014).

The consultants from TPG reported on very high satisfaction in the feedback from the leader groups participating in the workshops. The dynamics of such Gigamapping dialogic workshops was described as follows:

> Gigamapping helped them to have a "rambling" discussion that makes it possible to get an overview of a whole, relationships and consequences -and they continually worked on a proper (high) level. This demonstrates two typical problems for management groups; A) when they are decomposing a complex situation to discuss a portion at the time it becomes impossible (difficult) to stick to the case because it has so many links to other issues (and if one does not have a Gigamap each individual in the management team will jump on the links they associate without others having a chance to follow). B) When discussing individual cases the discussion tends to be too detailed – they dig themselves down into things and become more officers than leaders. As leaders, they should focus on the major relationships, balancing risk and burden of organization and priorities. It slips when they go too deeply into the issues. Gigamapping helps us to stay on the right (high) level. (Wettre, 2012) (Translation by the author)

Typical phenomena are:

- The capacity to have open and jumping discussion where jumps between issues are not a big problem because the map is used as a dialogic support. When jumping from one issue to another, represented in the map by jumping from one place to another, typically the participants would point at the new place on the map where they think the discussion should divert. This brings the rest of the group immediately to the new perspective.
- Synchronizing or creating awareness of unequal worldviews and perspectives. Even within teams that have worked together for a long time ruptures in perspectives are relatively normal.
- Controlling the level of discussion: The visual dialogue helps the discussion to remain on the same level or allows diving into details or zooming out to helicopter views whenever needed.
- Individual resources and different expertises are externalized and shared.

This mode of conversation is immensely valuable, but there has so far not been a developed format for this. A traditional meeting will be restrained by its agenda except the misc. section that normally comes at the end when time is short and people are tired. This format limits the content of the meeting to the points the leaders

[7] TPG has since merged with Rambøll.

Fig. 9 Different situations of dialogic Gigamapping. (Photos: The author and Linda Blaasvær)

regard of importance and it is not well suited for unearthing contradictions and ruptures. In addition, the Gigamapping process combines the free development of discussions with documentation. Very little is lost when done well (Fig. 9).

"On the Same Page" was a master studio project at the Oslo School of Architecture and Design collaborating with the directorate office for elderly homes in Oslo (Bogen et al., 2014). This case demonstrates the problems of ruptures when an organization is thrown into an unfamiliar process of reconfiguration. This caused severe communication problems.

The office was monitoring and administrating over 50 long-term care units. They were going through a major revision of their care model system by introducing a model with three different levels of care intensity (Home Care, Medium Intensity Care Home, Nursing Home) shifting from a model with two levels (Home Care, Nursing Home). The process was dependent on very high-level communication between large groups of administrators and staff.

The main problem was on the level of dialogue where the planning meetings were hampered with ruptures in the form of misunderstandings and lack of overview because of the complexity of the task at hand. A group of five master's students were taking on the project. The process was originally based on traditional meeting schematics with a plan for working meetings among the many groups. The participants reported and the students observed and recorded frequent communication breakdowns caused by the level of complexity of the process.

The students worked out a dialogue tool (Fig. 10) that was tested and developed through participatory design and at some point a workshop with over 50 participants

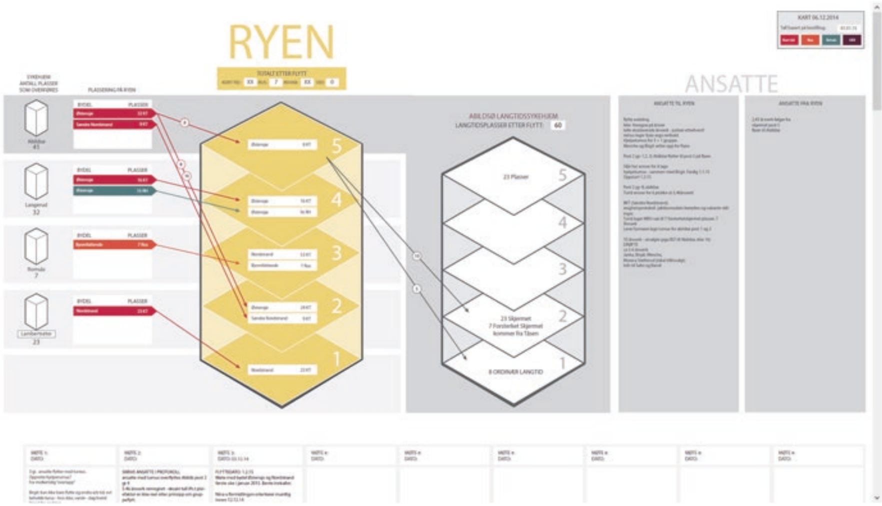

Fig. 10 Dialogue Map used by the directorate for elderly homes in Oslo (Bogen et al., 2014)

(Fig. 11). The effect of the tool was evidenced through observation and voice recordings of working meetings before and after the introduction of the communication and collaboration tools. The effect was very satisfactory, and the office adopted the tools, methods, and processes to further develop the tools on their own.

The final pillar in the praxiology of Systems Oriented Design that explains how we can overcome ruptures is the concept of the Rich Design Space (Fig. 12). This is the simple idea that very complex processes that need time also need space to make all information accessible. Such processes would normally produce a range of Gigamaps as well as other types of information visualization. A dedicated space keeps the information in play and helps a team to synchronize their different perspectives (Sevaldson, 2008).

New Developments in Bridging

Until recently, our conception of what the Gigamap's role might be in a collaborative setting was restricted to providing a shared picture of a complex field in an advanced design project. We have realized that these are constructed pictures, that we codesign a co-understanding of the complexity. In addition, it was clear that the sharing of facts, data, and information as well as opinions and conceptions from participants and stakeholders was formed or weighted and calibrated in the process of sharing them to form a coordinated understanding of the issues. Active co-interpretation is central.

Fig. 11 Example of Gigamapping process involving a large number of participants from a public service in Oslo. (From "On the same page" Bogen et al., 2014)

Fig. 12 A rich design space (IUVO project AHO 2017)

In Gigamapping one actively designs the interrelations between the different modes, domains, and types of information (this means a constructivist or rather a "designist" approach). This design process involves describing and designing how existing and found relations are represented, interpreted, and graphically illustrated. However, it also involves finding ruptures and designing new relations and developing ways of initiating them in an organization or process. From this follows that the strength of the Gigamap lies obviously not in the accurate description of the world but in an active designed interpretation. Further on, the Gigamapping process seamlessly transforms from the descriptive to the generative.

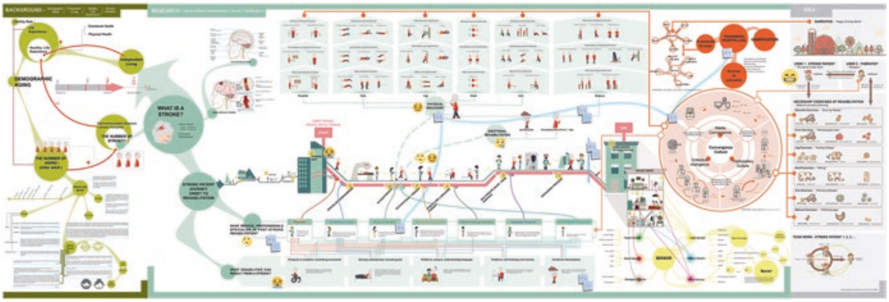

Fig. 13 Gigamap showing existing and proposed links and relations in a process of treating a stroke in the Norwegian public health system. (Cong Li, 2016, University College of Oslo and Akershus)

This implies designing a picture of not only how the world might be interpreted but also how it ought to be (Fig. 13).

Focussing on these qualities of the Gigamap forces a reinterpretation and reflection upon what the Gigamap really represents. Revisiting the role of the designer and the role of the Gigamap and Systems Oriented Design has led to a shift and clarification of the view on the role of the Gigamap. This shift has moved attention from the myriad (quantity) of information, entities, and links to the qualitative appearance of the map as a whole. This is summed up in the Sense Sharing Model.

The Sense Sharing Model

A significant value of the Gigamap is that it produces aligned and shared *sensitivities* for the task at hand. The Sense Sharing Model is a perspective that describes shared sensitivities. Codesigners can share as much information they want and codesign the Gigamap and create a shared picture, but they can still have a different view on the issue. Therefore the attention has to move from information fragments to holistic pictures.

The Sense Sharing Model builds on a common notion of sensibility training that one could argue is implicitly central in design education. However, it also refers to sensemaking as described by Russell et al. (Russell, Stefik, Pirolli, & Card, 1993) who relate sensemaking to systems engineering, Weick (Weick, 1995; Weick, Sutcliffe, & Obstfeld, 2005) and others who relate sensemaking to organizations, and Lurås (Lurås, 2012) and Aaltonen et al. (Aaltonen, Barth, Casti, Mitleton-Kelly, & Sanders, 2005) who have related sensemaking to systemics and complexity. In this paper and context, these sources are of less importance than the designerly sensibility skills that have been inherently and tacitly present in the practice of design from the very beginning of the discipline with much older roots into the arts and craftsmanship. I argue that activities that bear relationship to sensemaking have been central in design for a long time before it was defined and described by Weick and others. Making sense of things through visualization, narratives, and solving needs and problems and providing experiences has been at the core of design and Design Thinking. It is unthinkable without this component of common sense, judgement, and reasoning. Kolko describes sensemaking as an inherent part of design synthesis (Kolko, 2010). He also describes how mapping might be central in sensemaking:

> Because of the complexity of comprehending so much data at once, the designer will frequently turn to a large sheet of paper and a blank wall in order to "map it all out." Several hours later, the sheet of paper will be covered with what to a newcomer appears to be a mess—yet the designer has made substantial progress, and the mess actually represents the deep and meaningful sensemaking that drives innovation. (p. 16)

Klein and Moon relate sensemaking to a systemic perspective by describing sensemaking as oriented towards understanding relations, but also related to other aspects that are naturally present in the design process:

> By sensemaking, modern researchers seem to mean something different from creativity, comprehension, curiosity, mental modelling, explanation, or situational awareness, although all these factors or phenomena can be involved in or related to sensemaking. Sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively. (Klein & Moon, 2006)

While Kolko talks about sensemaking as an internal individual process, Klein and Dervin talk about sensemaking as making sense of other people, e.g. users. Sense Sharing is about both these modes and about additional issues, e.g. sharing between individuals in a work group. It includes sharing sense of non-human beings and non-biotic phenomena. These could be natural or synthetic like the structure of a city.

Since the start of the research with Gigamaps, it was clear that there was more to it than the facts only. This has led to a long process of developing the insight about this form of mapping. This has developed through two steps of concept development. The first step was the realization and clarification of the Gigamap as a design artefact. This had implications on how the mapping process was seen and on the relation between the map and the reality it first depicts and later redesigns. This realization did solve some of the qualitative questions the mapping raised. However, there were still more tacitly sensed issues to it. Intuitively we were drawn towards certain types of maps that depicted richness and depth on the cost of clarity. I needed to clarify this attraction to the messiness of certain maps (Fig. 14).

By studying exemplars of such maps, the realization emerged that what these maps mainly communicated and shared were soft but nevertheless very important and central issues when bridging ruptures. Instead of dominantly communicating information, these maps communicated and depicted a sense of the qualitative features of the system. These features are the components of the Sense Sharing Model.[8]

[8] I relate this theoretically to Zwicky's Morphological Analysis (MA) but a designerly less ordered version based in design work. This has some disadvantages compared to MA but also some advantages, though this discussion would exceed the frames of this article (Ritchey, 1998).

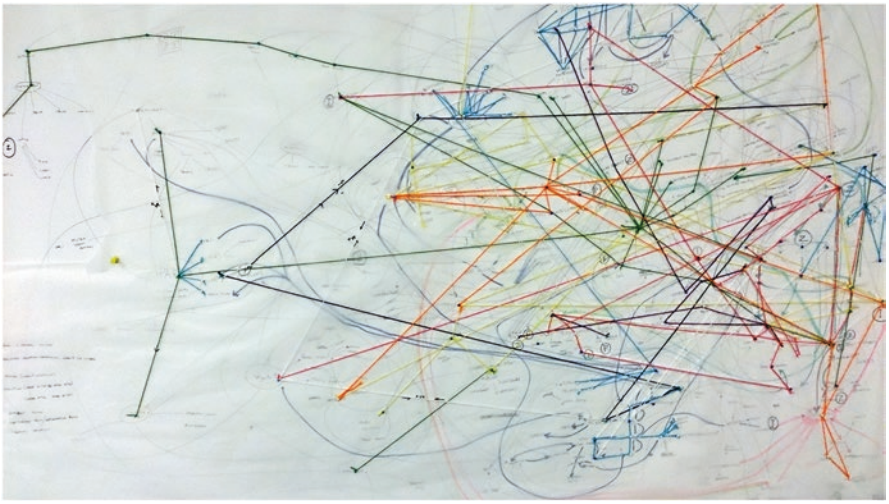

Fig. 14 Richness and depth on the cost of clarity. Such maps were intuitively attractive, but what they depicted and emphasized was not immediately clear. The map is developing the relations found in a task, given to master's students at Chalmers University, Gothenburg. The task was to design an integrated social housing project for immigrants on the campus of the university. (Karin Backlund, Maxwell Kevin Otieno, Evelina Peterson, Chalmers Architecture, 2015 Photo: Birger Sevaldson)

These were pinpointed to include the following features:

- Sense of the field
- Sense of Gestalt
- Sense of degree of complexity
- Sense of timing and dynamics
- Sense of needed effort
- Sense of resistance

Sense of Field

A shared sense of the field in which the client organization or the project is situated. How extensive is it? How solid or blurry is its boundaries? How enclosed or fragmented is the field? How vast does it stretch? How diverse is it? Failing to share this sense of the field can result in fragmented project work.

For example, when designing a car, this involves a multitude of experts spanning from all sorts of engineering, software development, ergonomic, form-giving and styling experts, interior and material experts, cultural and aesthetics, marked and business understanding, emission, laws, regulations, environmental issues, safety, etc.

Sense of Gestalt

A shared sense of the main figure of the system at hand. Is there a clear head? Is it a top-down or bottom-up organization? Is it old and grown over time? Is it worn and fragile? What shape depicts it best? Failing to share the sense of Gestalt might result in hidden ruptures in the process.

For example, if one wants to induce organizational change, one needs to know who to bring on board for what and how resilient the organization is.

Sense of Degree of Complexity

A shared sense of how complex the challenges ahead are. If the team has very differing views on how challenging the task is, there is a serious rupture. It is not needed to understand the system in all its detail to generate a sense of degree of complexity.

For example, marked and business strategies need to take into account technological, cultural, and economic challenges for an innovative product. Ideally, the strategies also need to understand trends and politics as well as the need for sustainability.

Sense of Timing and Dynamics

A shared sense of how dynamic the system is. Is it changing quickly or slowly? Is it able to absorb change within a reasonable span of time or will change take longer time. How is the timing for suggested interventions? Failing to share the sense of the dynamics of a system can result in serious ruptures and desynchronized and erroneous planning.

For example, architects used to plan according to static room programmes instead of planning for revisions, flexibility, and change from the outset.

Sense of Required Effort

A shared sense of the effort needed to successfully implement a suggested systemic design intervention. Is it expensive? Are there technical difficulties? Failing to share this sense leads to serious implementation problems.

For example, information technology projects are notoriously known for breaching economic and time frames.

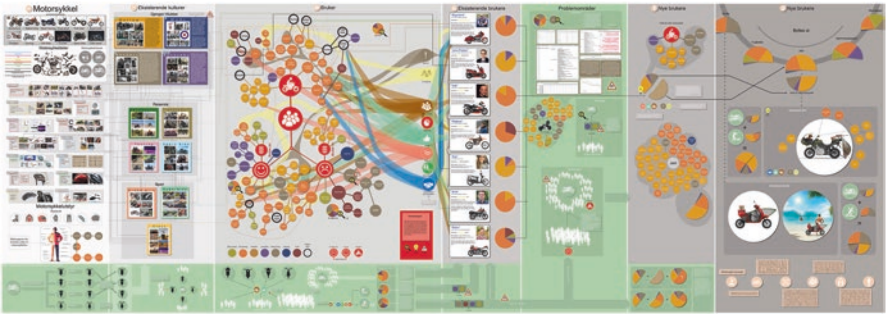

Fig. 15 A Gigamap capturing the complex world of motorbikes. Sharing a sense of the field would be important for those who want to design an innovative motorbike. (Arnt Kåre Sivertsen and Levi Lynau Celius, University College of Oslo and Akershus 2016)

Sense of Resistance

The inherent resistance to change that affects the systemic design intervention. Resistance can be found on all levels in the system, its environment, the landscape it lives in and globally (Fig. 15).

For example, sharing an understanding of technological, economic, and cultural thresholds as well as the difficulties in meeting the needs for sustainability is important.

How to Practise the Sense Sharing Model

The significance of the Sense Sharing Model is mostly about building awareness of what the goal of Gigamapping is in collaborative settings. It is beneficial to emphasize the less tangible output from this mapping process. Besides the mapping of real-life data, the interrelating of mixed information sets, and the externalization and internalization of knowledge about a subject, it is important to realize the value of synchronization of the different individual perspectives. The Sense Sharing Model partly explains why Gigamapping, in the overwhelming majority of cases, feels useful and meaningful in group work across disciplines and positions.

On an initial level, the model can be practised as checkpoints for discussions to repeatedly check the shared awareness of how synchronized the views in a collaborating group actually are.

However, the steps forward would include developing frameworks for sessions for each of the features where they are discussed through using the Gigamaps as the backbone where it would be possible to point out and grade the different sense sharing levels. This makes sense because there could be a high degree of sense sharing at certain areas or points in the Gigamap, while the shared understanding could be broken at other points.

Conclusion

In this paper, I have addressed some seemingly vague issues that have emerged from the practice of Gigamapping, issues that are crucial for the dialogue that is so central for participatory and interdisciplinary collaboration. The most important issue is to identify those vague ruptures in the interpretation of the map, ruptures that have been frequent and that at the same time have been unveiled and often solved through Gigamapping. This issue has not been addressed particularly nor solved methodologically earlier. Though this text emerges in the midst of a development process, it has quite central implications on how we look at the role of the Gigamap in SOD. While the usefulness of discussing and scrutinizing these issues in a SOD process seems obvious, future developments would refine and develop and evidence this further.

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Local Ruralism: Systemic Design for Economic Development

Silvia Barbero

Abstract Rural regions have high potential for local economic development offered by social innovation (Neumeier, Sociologia Ruralis 52:48–69, 2012) and social transformation and transition (Markard et al., Research Policy 41:955–967, 2012).

The aim of this article is to unlock the potential of systemic innovation in rural development through research insights and practical methods. Theories and practices can define a framework to be used and exported in different contexts.

Design approaches inform first principles for human social systems and encourage social innovation processes for the improvement of the quality of life and the economic well-being of people (Bistagnino, Systemic Design: designing productive and environmental sustainability. Slow Food Editore, Bra, Italy, 2011). The explained case studies are practices undertaken by the author to directly bring findings from a design phase through to implementation. The three cases are set in three different geographical contexts (Mexico, Italy, and Spain) with declining rural situations. The empirical evidence for what might be the necessary enabling condition for rural development remains limited, so this direct experience can give new insights on systemic innovation as enabler for rural development.

The ambition underlying these projects is to develop pertinent knowledge, clear frameworks, and concrete guidelines, which constitute a new method to facilitate the actions of systemic networks in rural regions.

Introduction

Today, citizens of many rural regions find themselves locked into patterns of economic decline. Although urbanization is creating enormous pockets of poverty in large urban centres, there are more poor people in rural areas contending with social and economic aggravating factors: lack of visibility, equipment, and basic infrastructures (Ramos & Malagòn, 2010).

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While fully understanding the process of rural development fully requires a multiplicity of different theories (Lee, Árnason, Nightingale, & Shucksmith 2005), we argue that speculative and empirical approaches can help us understand the dynamics of realities. In other words, a focus on theories related to systemic innovation design (desk research), and on analysis of real case studies designed by the same researcher (field research), provides a means of understanding framework and concrete guidelines to facilitate future actions of systemic innovation networks in rural regions. In terms of rural development, as Ray (2006) said, the neo-endogenous approach, with its tension between bottom-up and top-down choices, has two primary characteristics:

1. The economy is reoriented to maximize the retention of benefit, within the local territory by valorizing and exploring local resources—physical and human.
2. Development is contextualized by focusing on the needs, capacities, and perspectives of local people.

The development model emphasizes the principle and process of "local participation" in the design and implementation phase, through the adoption of cultural, environmental, and community values (Ray, 2006). Regional development processes are strongly dependent on people's ability to develop sustainable structures that, on the one hand, facilitate all forms of innovation, creativity, new ideas, and visions in acting and, on the other hand, maintain the essential stability (Neumeier, 2012). Similarly, Cooke (1998) stresses that with the convergence of evolutionary theory and industrial district theory, variations in the development of regions can no longer be explained only as a result of physical and financial resources only. Instead, different organizational and technical abilities of regional actors can make the difference in local development, because of the application of practical and technical know-how with the available regional resources.

As for its structure, the next section introduces the methodology used to define an exportable framework, informing the role and the use of desk and field research (Celaschi & Deserti, 2007). This section is followed by a discussion on design approaches and how they can build a systemic innovation specifically for the development of rural areas. The next part is given over to an exposition of personal experiences by the author in three case studies, from the preliminary stages to the implementation. Finally, we can merge some results and conclusions with speculative and empirical duality.

Methodology

Despite an increasing interest between both policy analysts and academics in the notion that innovation might be an enabler for rural development, there is so far a limited empirical evidence base on which enabling conditions are necessary. Utilizing a combination of desk (literature) and field research leads to a more in-depth understanding of reality from different viewpoints, which is crucial when exploring topics or issues involving a large range of actors and stakeholders. This research is heavily focused on action case method (Vidgen & Braa, 1997) in order to move from understanding to prediction and to change. The basis of this research is therefore the use of diverse kinds of data sources and a mix of qualitative and quantitative methods. The literature review detects the existing information already written by others, with an important identification of the sources and their reliability (literature, case studies, site visits, interviews, industry interactions). The desk research moves from the most quantitative data, like database, statistics, reports, case studies, and scientific reviews, to other qualitative sources such as social media. In the same way, the field research moves from more quantitative data, such as data recording, field mapping, and surveys, to more qualitative, approaches such as observation and ethnographic empathy. The combination of desk and field research aims at understanding the facts in order to define an original framework (Celaschi & Deserti, 2007). These two steps are not temporally subsequent, but they reiterate many times with intermediate situation of visual framing and gap analysis in order to redirect research in the right way (see Fig. 1).

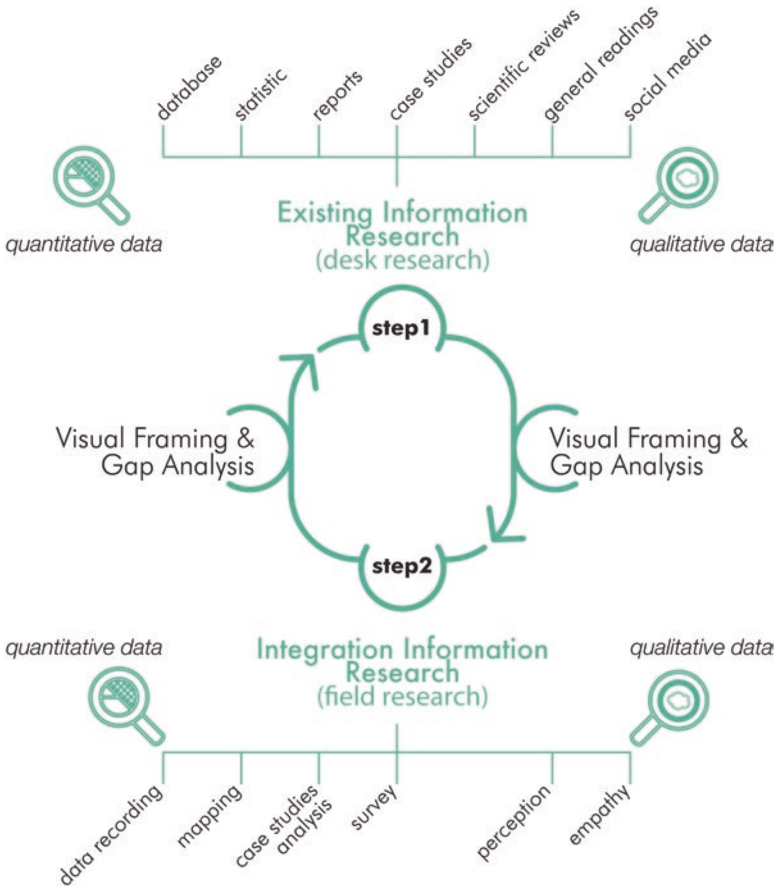

Fig. 1 Relation between desk and field research (courtesy of Andrea Gaiardo)

In the first step, the design approaches are analysed in order to understand how they can contribute to systemic innovation for the development of rural areas. The living systems theories are taken into consideration and can give us many insights for future improvements, from generative science to systemic design.

In the second step, the analysis ex post of real selected projects allows to map and evaluate links to innovation, governance, and rural development. Three case studies directly improved by the author are analysed, taking the advantage of direct and from inside knowledge of them. The empirical research is focused on identifying the enabling conditions and limiting factors for rural development, in order to define a new framework for the enhancement of smart, inclusive, and sustainable growth in declining rural areas.

Theoretical Background

The challenge of the desk research is to put together the latest theories connected to sustainable development that integrate the "triple Ps" (people, planet, profit), incorporating many contributors from social sciences and humanities, natural sciences, and economic studies, to define the complexity of this topic.

On the basis of the complexity in living systems theories, many next developing theories on social dynamics, natural behaviours, and industrial processes applied that concept on artificial systems. The generative science shows how finite parameters in the natural phenomena interact with each other to generate infinite behaviours.

This science explores the natural phenomena at several levels including physical, biological, and social ones. The generative science was further enhanced by Wiener's (1948) cybernetics. Cybernetics unified the physical, biological, and social sciences into a holistic discipline of artificial and social systems control and communication. Similarly, a generative philosophy evolved through von Bertalanffy's general systems theory (GST). He stated that "a system is a set of unities with relationship among them," underlining the relational aspects among the several parts and the global essence of the whole system. Contemporary ideas from systems theory have grown within diversified areas. As a transdisciplinary, interdisciplinary, and multi-perspective domain, GST brings together principles and concepts from ontology, philosophy of science, physics, computer science, biology, and engineering as well as geography, sociology, political science, psychotherapy, and economics among others.

Complexity models of living systems address also productive models with their organizations and management, where the relationships between parts are more important than the parts themselves. Treating organizations as complex adaptive systems, the productive, management model emerges in economical, social, and environmental benefits (Plsek & Wilson, 2001). In that field, Porter's industry cluster (1990) evolved in more environmental sensible theories: Frosch and Gallopoulos' industrial ecology (1989), in which the resources of industrial processes move through the system to become waste and then output, can become inputs for new processes. Furthermore, in Chertow's industrial symbiosis (2000), the geographic proximity is neither necessary nor sufficient; turning waste into business opportunities reduces demands on the earth's resources and provides a stepping stone towards creating a circular economy (CE) (Pearce & Turner, 1989).

A further contribution to CE comes from the systemic design (SD) discipline, driven by different academic groups around the world. SD enhances the dialogue among the different actors involved in complex anthropic systems, in order to optimize the throughput of materials, energy, and information from one system to another in continuous dynamic balance. SD is being developed within design practice and through the Systemic Design Association as of Oct 2018 focusing on different aspects of the issue:

The systemic design research team at Politecnico di Torino (Italy) is active in research and didactics. There is a 2-year master of science in systemic design named after Aurelio Peccei. This approach, put forward by Luigi Bistagnino, focuses on the relationship between the outputs and the inputs of a system, by viewing waste as a valuable resource.

The Strategic Foresight and Innovation MDes programme at OCAD University (Toronto, Canada) sustains a systemic design initiative led by Peter Jones. Emphasis is placed on teaching complex problem finding, framing, and solving, to envision and develop sustainable futures with design action research, system mapping and process design, and dialogic design.

Systems-oriented design is the SD approach developed by Birger Sevaldson at the Oslo School of Architecture and Design (Norway). It seeks to train designers' ability to cope with a larger degree of complexity and to take more responsibility for the consequences of their actions.

Systems thinking and design is part of the academic programme at the National Institute of Design (India) in the design department established by the late M. P. Ranjan and led by Praveen Nahar. They apply a systems approach towards complex issues and wicked problems with high level of ambiguity, uncertainty, and complexity from socio-cultural-economic-environmental perspectives.

The systems theories can play an important role in rural development, such as Ison's participatory rural appraisals (PRAs) with their conceptual and process issues relating to design (Ison, 2000). The systemic design approach, in the most recent evolution, is particularly attentive to the territorial implications and valorizations. In that sense, we can call it systemic design for sustainable rural development, where the management of local resources and wastes can generate new territorial businesses to guarantee distribution of wealth to local communities.

Action Case Accounts

Comparing case studies, we draw attention to the human activities needed in rural development and examine local contexts.

Case studies can provide support for a framework for the development of rural areas—possibly to identify the distance points from theories and practices and to verify the differences in design (project) and implementation (action) phases among the case studies. We choose the following three cases for their different geographical contexts (Italy, Spain, Mexico) and also for their social, economic, and technological background. The common characteristics are the need for stimulating economic and social development in rural communities and the active participation of the author in their design and implementation.

We might state in advance that a universally recognized definition of “rural development” does not exist, because development is the result of different factors (physical, technological, economic, socio-cultural, institutional). The term “rural” defines all the territories that are not urban (or allocated for urban expansion), where the main activities are agro-silvo pastoral and the habitation density is very low. We can consider sustainable rural development as a process that allows a rural population to generate value at their local potential while respecting the environment (Capello & Hoffmann, 1998). The three cases described below fit those characteristics: The EN.FA.SI. project is based in Cuneo province in north-western Italy, the Ahuehuetla project is based in Ahuacuotzingo village in Guerrero state in Mexico, and the Systemic Buying Group project is from the Lea-Artibai district in Spain’s Basque Country. Cuneo is the main city of the province with less than 600,000 inhabitants and a density around 450 inhabitants per km^2, but the rest of the province has a low density with primary activities of agriculture (cereal and fruit production), forestry (elm, oak, chestnut tree, willow), and grazing (cattle and sheep). Ahuacuotzingo is a village in southwest Mexico, with about 25,000 inhabitants and a very low density (65 inhabitants per km^2). Farming is important for land use and for the management of natural resources, but just for subsistence, as well as farm animals. Lea-Artibai is a province located in the northern part of the Basque Country and derives its name from the two rivers it hosts: Lea and Artibai. It overlooks the Gulf of Biscay; its culture and economy are closely connected to the sea, especially for the Lekeitio and Ondarroa. These are the main towns in the area, together with Markina-Xemein, where most of the people are concentrated (26,000 inhabitants), but the population is mainly diffused across many small villages in the countryside.

The author was a team coordinator in these three projects from the early stages, so the data collection, the critical analysis on the work direction, and the project evolution are enriched with personal details and knowledge. With projects personally led, from the design stage to the implementation and the real activation, they last an average of 3 years: EN.FA.SI. project lasts from 2011 to 2014, Ahuehuetla and the Systemic Buying Group projects started in 2013, and they are still ongoing.

EN.FA.SI. Project

The EN.FA.SI. project (l’ENergia e il FAgiolo in SIstema), supported by the Piedmont region with POR-FESR 2007–2013 funds on productive transition and innovation, aims to develop a specific area in north-western Italy (province of Cuneo) through a process of designing for food supplies.

Analysis

The project takes place in the province of Cuneo (Piedmont), a varied territory characterized by the mountains, the hills, and the Po river valley. The Cuneo area is rich in natural resources, history, and ancient traditions deeply rooted in the territory. The manufacturing industry and service sectors are the most incisive for the local economy; however, the province of Cuneo is traditionally tied to agriculture and breeding, characterized by high-quality crops and excellence in agricultural and food products. The cool temperatures of the lowland area, the high solar radiation, and the drastic temperature range make it a suitable area for growing the Cuneo bean (Fagiolo Cuneo). The project analyses the scenario, the environment, the territory, and the habits of its inhabitants, applying the systemic approach to the supply chain of the Cuneo bean.

Project

The project studies not only the linear process but also the inputs and outputs involved in each phase, to generate added value from what is usually considered waste. Environmental problems generate both difficulties and the main opportunities for innovation related to Cuneo's bean supply chain, from cultivation to distribution, from packaging design to rediscovering and promoting traditional recipes. This research evaluates the input and output of all stages of production, studies the energy needs and the flows of matter and energy, and proposes a system to ensure zero impact on the environment. Cuneo's bean supply chain is of great importance for the cultural history of the province, highlighted by the presence of a "consortium" set up by the Chamber of Commerce of Cuneo in 1989, to promote this product registered as TFP (traditional food products) and PGI (protection of geographical indication).

The planned improvements introduced during many years of research and related tests cover many aspects such as water consumption, the use of pesticides and chemicals, the waste management in the field, and different production stages—including biomass, broken or non-standard beans, the cooking, and dehydration wastewater. The biomass was tested for the production of 100% recycled paper. The feasibility of producing goods made from bean pods was also investigated, bean pods which currently are left unexploited in the field, such as food supplements, natural cosmetics, biopolymers, and biofilms (see Fig. 2).

Actions

Among the other results, the project led to the introduction of two types of dried beans characterized by low cooking times:

- Precooked bean without preserving liquid
- Bean flakes obtained from broken beans with a lamination process

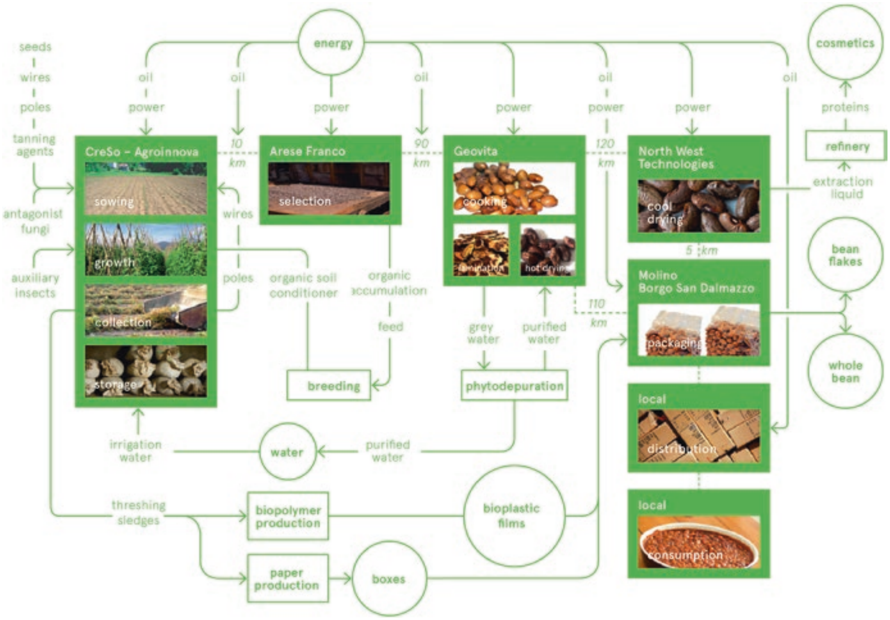

Fig. 2 Cuneo bean complex system

Both processes extend the shelf life of the bean and introduce new products on the market, with new textures and low cooking times. These features expand the potential market, extending the products to new targeted consumers.

Packaging represents the means of communication and dissemination of the project and aims to increase the consumer's awareness about the origin, traceability, and tradition related to the bean, highlighting the systemic approach and the management of the whole supply chain.

The project impacts have been revealed in:

- Environment: land conservation, protection of soil and native species, the consolidation of local culture, clean industrial processes, and efficient logistics
- Economy: increasing productive activities in the area, niche business development, and integration of different production activities
- Technology: process innovation and efficiency
- Society: increasing local workplaces, enhancement of the know-how mainly held by the elderly, and the application of scientific innovation in the field

The project was logistically complex, involving many local small and medium enterprises (SMEs), and it delivered many new products for the new local market. The programmed changes in the system provide an evolution in industrial processes that were modified from linear (resource extraction, processing, and production of manufactured goods and scrap) to systemic and integrated, by creating a network of companies with zero emissions.

Conclusion

EN.FA.SI. project supports the rural development, bringing both scientific research and technology transfer in sectors closely linked to traditional production techniques. By addressing the general public, the project was able to convey its values, and some improvements were easily implemented in the production activities, raising critical awareness about inefficiencies and consolidated malpractices, by increasing productivity and protecting plants against unauthorized human treatments.

Ahuehuetla Project

The project started with the cooperative of farmers in a small village in Guerrero state (Mexico): Ahuehuetla. The project is promoted by the cooperative and the Red Mexicana de Mujeres, with bottom-up processes. It aims to develop this rural area through a participative process of designing and improving local activities.

Analysis

The area is characterized by low population and enterprise density, high unemployment, and a history of emigration to the United States. Since 1980, Mexicans have been the largest immigrant group in the United States: In 2013, approximately 11.6 million Mexican immigrants resided in the United States (up from 2.2 million in 1980), and they accounted for the 28% (41.3 million) of the country's foreign born (U.S. Census Bureau, 2013). This situation generates a radical change in lifestyles and food consumption and a loss in material culture, as immigrants often adapt by imitating the host culture, risking the loss of their own local and traditional know-how. In recent years, many seek to improve their quality of life and well-being by returning to farm the land in their hometown. The population of this rather isolated rural area reveals to be intimately and intensely linked to the territory and to have a strong sense of belonging and collective strength. In addition, the farmers of the Ahuehuetla Cooperative are very motivated for a substantial change towards sustainable rural development.

Project

A systemic design approach requires a complex process consisting of several stages, managing many variables and developing the active participation of all actors and stakeholders. This means that the project needs many years to be implemented, but even if it is not finished yet and complete, the first results can be experienced in the context.

The Local Agricultural Cooperative (LAC) was born with the five farmers that are involved from the beginning of the project and by two other interesting realities on the territory: a group of five women producing panela (a typical local product, a sweetener resulted from the transformation of sugar cane juice) and another one of women who own and manage an organic greenhouse. The aim of the LAC, called Ahuehuetla, is to cooperate and collaborate on the basis of some shared values to address common challenges and provide mutual benefits. The goal is to work with local resources and show that this rural area is not poor, redefining and designing new flows of matter and energy. In this way, the farmers could become stronger under different perspectives: the support in investments that alone could never be realized; and the sharing of equipment, tools, and spaces.

Action

Within the project of Ahuehuetla Cooperative, we also dealt with the design of their organizational logo, which is the central visual element that helps to identify and remember the brand. As happen in every company, this icon is a real symbol: The main purpose of it is to summarize and underline shared concepts and values from farmers. It is not only a graphic action, a graphic sign, but it is a way to define and promote a strong and precise identity for the farmers and the entire community. Other fundamental preliminary results are the improvements made in 2015:

- Two biodigesters were installed for disposing organic waste and to generate biogas used in the kitchen restaurant.
- Kitchens were equipped with chimneys, a small improvement but very important considering the diffusion of respiratory diseases caused by the production of smoke in the kitchens.
- Plantation of 40 fruit trees for the production of oranges, lemons, mangoes, and bananas to be used directly in the restaurant or processed in the laboratory.
- Construction of a playground for children using discarded materials.
- Refurbishment of the roofs, with the metal sheets replaced by waterproof structures (fabric covered with a natural substance derived from the viscous liquid extracted from nopal, a typical and widely present plant in the territory).
- Construction of a greenhouse for the production of vermicomposting.

Furthermore, there are important intangible aspects inherent in the culture: The community is supporting each other, sharing problems and solutions. The creation of the Ahuehuetla Cooperative also allows the farmers to broaden their perspectives:

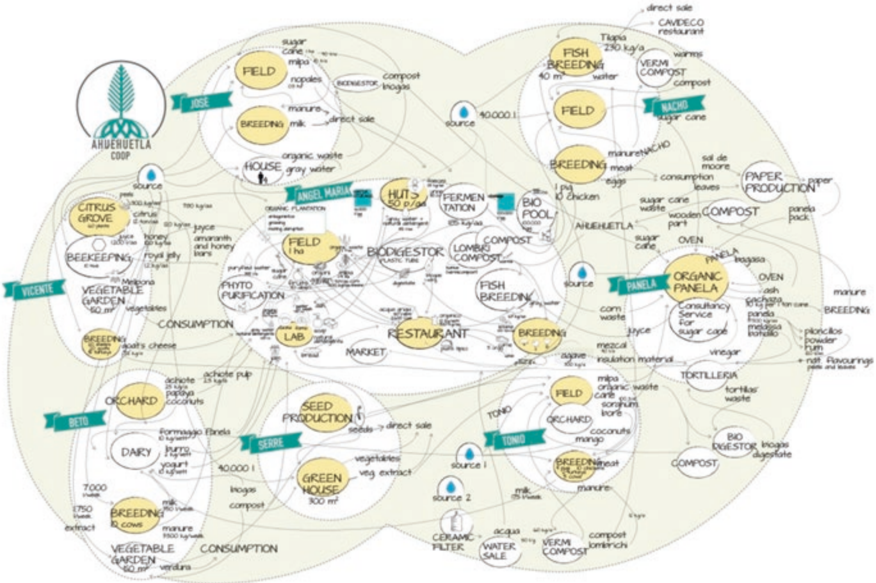

Fig. 3 The complex system of Ahuehuetla Cooperative after the systemic design project

If currently they are limited to produce what is enough for their subsistence and obtain a minimum gain, all together they can act with a vision closer to a small or microenterprise. This perspective starts from the increase of production, because, right now, farmers grow on only a small part of the land they have, despite the availability of water and staff. In this way it is possible to achieve quantitative results: the increased number of products and the newly formed relationships among the farmers themselves, the consumers, and the locals (see Fig. 3).

Conclusion

This research presents social innovation from a rural development perspective. The classical formulas of industrial process and product innovation are inherently part of the economic paradigm of global growth, which often introduced the cause of deeper social-ecological problems, such as environmental degradation and social displacement. This is also why we might critique the contemporary discourses of innovation concerning their relationship to social meaning. Social innovation processes work especially where markets are insufficiently large or integrated, such as local and rural zones, and where public policies do not offer adequate solutions to the challenges. This is especially where governance institutions are weak to find solutions for complex problems and hesitate to generate answers to the needs in local systems. Social innovation processes are capable of mobilizing, openly and continuously, a large number of actors active in the local system who are seeking useful solutions (Murray, Caulier-Grice, & Mulgan, 2010).

Expected results of the study further implicate social, economic, environmental, and health aspects. The farmers of the Ahuehuetla Cooperative can become self-sufficient not only in terms of energy and food production, improving the quality of life, but also increasing the supply of food products, both unprocessed and processed (Fig. 3).

Azaro Project

A project was designed to promote the development of local agriculture and to better link production activities and citizens to the territory.

Analysis

The area of Lea-Artibai is located in the north of the Basque Country, and it is characterized by strong cultural identity and belonging to the territory. The agrofood sector is traditionally linked to fishing sector, which is currently experiencing a deep crisis. Agriculture is a marginal activity characterized by micro-small enterprises and focused mainly on self-sustainment and on selling products in small local markets. The main resources of this territory are the forests of pine and eucalyptus: Even though these are not indigenous trees, they cover the vast majority of the hills.

The production sector is made of numerous micro-small activities and some medium and large enterprises, mainly related to the processing of fish, plastic, and metals and to the manufacturing of industrial components. A peculiar feature of the territory is the predominance of the cooperative organization of companies.

The first phase of analysis carried on remotely and on-site highlighted strength points and problems of the current situation: on one side, the richness of the natural, cultural food and wine heritage and, on the other, the predominance of non-local forests, the lack of connection between the industries and the local territory, and the shortage of land to further develop agriculture and the crisis of the fishing sector.

Project

Based on these elements, the aim of the project is to promote the sustainable local development of Lea-Artibai through the implementation of the systemic approach in different activities within the area, in order to create a complex system of interconnections able to generate the renewed territorial development.

The next steps of the project include the interpretation and re-elaboration of the gathered information and the definition of the measures to implement. The main local problems are considered as leverages for the change and enable the individuation of potentialities that represent the elements for further studies. Starting from them and from the information gathered, a new system that answers to identify problems is designed. The theoretical outcomes and benefits generated are studied; the system is then progressively implemented and results are monitored (Battistoni, Pallaro, & Arrizabalaga-Arambarr, 2016).

The starting point of the project was then identified in the combination of potentials offered by cooperatives (human potential of their employees) and by local food producers (production potential of their high-quality goods) to overcome the problems experienced by both actors.

Action

The 11 cooperatives located in Lea-Artibai currently employ about 1400 workers. Eika Koop, a cooperative producing electric components for kitchen, is the second largest one in the area, with almost 500 employees. If we consider their families, approximately 1500 people are directly and indirectly involved. Eika is located in an industrial area, but has no relations with neighbouring enterprises nor with the surrounding territory. Its employees are considered only as workforce and not as a potential for other activities. Their working hours often coincide with opening hours of local shops and marketplaces; thus, to satisfy their necessity to buy food, employees usually go to supermarkets, lowering the quality of their diet, consuming products coming from all over the world, and giving money mainly to platforms of logistics that manage their fluxes. On the other hand, micro and small local food producers are able to offer high quality of products, but experience many difficulties in finding customers and sustain high production costs. The shop Produkt On, born to sustain the promotion of local products, is a first step to overcome these problems. It currently sells fresh and preserved food coming from local producers of Lea-Artibai and Durangaldea (the neighbouring district) and members of a cooperative named Oiz Egin. However, its opening hours coincide with working hours, a condition that limits the effectiveness of its service. The project focuses on the creation of a Systemic Buying Group (SBG), identified as the appropriate model to satisfy the needs of the involved actors. The analysis of several case studies of buying groups was performed to understand the feature of each of them in relation to their context; as a result, an underlying functioning schema emerged (see Fig. 4). The members of the SBG will be chosen among the employees of Eika according to their interest in the project. A pilot group of 50 employees will be formed and an internal coordinator elected. Produkt On will be the coordinator and will manage the order, organizing requests among its producers—the partners of the cooperative Oiz Egin, already linked to the shop—and assembling the baskets of products. These will be then delivered to the cooperative where employees could easily collect them. After use, the packaging of baskets will then be returned to Produkt On and producers.

The SBG generates positive impacts that interest all actors. Besides saving time and money, employees will improve their diet thanks to the high quality of local products; this will be reflected in better health and reduced number of absences from work that will be a benefit for Eika. Through the project, Produkt On will gain visibility and will increase the number of producers cooperating with it. Local producers will more easily find customers and will increase their income.

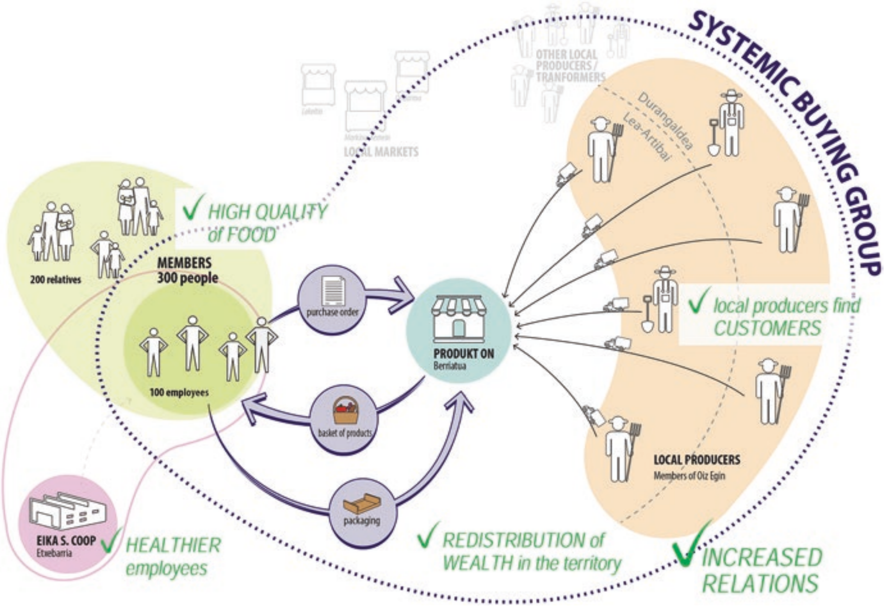

Fig. 4 Systemic Buying Group structure and actors involved

Conclusion

Globally, the project leads to a redistribution of the wealth among the local actors of the territory, giving support to the local economy. The project creates a local development based on:

- Environmental sustainability, leading towards zero emissions
- Economic sustainability, for the creation of a new economic model
- Social sustainability, for the new equal relations established between actors and for the benefits interesting employees

The developed project aims at becoming a driver for The change of a territory where the crisis of the wood and fishing sectors has highlighted the necessity to rethink the basis of rural development in the long term, starting from the enhancement of the territorial potentialities.

Summary of Findings

The three case studies show three different rural situations: The first one is very focused on agriculture (even if located in a wealthy area of Italy). The second case project is from a very poor rural region with many social problems. The third one is focused on other activities not so well connected with the territory. However, we can analyse and summarize common results of the case studies and peculiarities of different contexts (Zahedi & Otterpohl, 2015).

One of the main aspects of the rural area is the strong relation with the agricultural sector, so all the projects started from the field for the systemic goals of increasing the wellness of local communities. The EN.FA.SI. project is working on a single production (Cuneo bean) and can spread the benefit of a better production on the entire territory, without incentivizing a monoculture. The Ahuehuetla LAC wants to increase the local agricultural production to share the benefit with the community. The SBG helps the workers to have a higher-quality diet, connecting the local producers with the consumers. So even if design solutions differ among the three contexts, they share similar starting points to increase the quality of life of people living in rural areas—because the primary goal is to increase the quality of local production in terms of choice of the right cultivations, improvement of the processes at environmental and technical levels, and sharing the benefits.

Another important aspect is the role of the local actors in the complex process of rural development. We choose these three cases because the author is actively engaged in the design and implementation processes, providing a perspective of the systemic researcher/designer and the relationships with the other actors involved. The team of actors involved in every phase of the project is multidisciplinary and includes the participation, on several levels, of the professionals and of the local inhabitants of the rural community. In that context, the designer assumes the role of "designer mediator" as described by Celaschi:

> …his/her aim is to build or consolidate the team and the mediated integration between different types of knowledge and different specialism. (Celaschi et al., 2013)

The systemic designer designs the throughputs that transform the output into input in a continuous metabolization within the complex system; he/she must manage the awkward, often complicated, dialogue from the different actors in all the phases of the project; he/she will also collaborate with all the involved actors. The basic ecosystem is the local community with its active participation mainly in the implementation phase. It is crucial for the success of the project, so it should be engaged from the early stages if we want to obtain long-term results. We have experienced directly in the field the difficulty of dialogue with local community and farmers, not for language differences, but for cultural barriers. Therefore, the systemic design has the responsibility to build a trustful environment to evolve the relations among actors.

Another important actor is crucial to build up trust, a role we called "connective actor" (Bicocca, 2016a, 2016b). This role can be of a single person, as in the case of Ahuehuetla LAC, or an organization, as in the other two cases. In Mexico, we are working closely with Nuria Costa Leonardo, a Nobel Peace Prize nominee from 2005. She has been involved in numerous projects with the Red Mexicana de Mujeres (REMEMUR) on socially responsible business in rural development. Costa

Leonardo has already earned the faith of the local community, and she strongly believes in the quality of our design work; she helped connect our experiences and build a conducive social environment affording dialogue and the open exchange of experience. In Italy and Spain, we are working respectively with Coldiretti, a farmer's association, and Azaro Foundazioa, a local foundation for business development, both of which are already well known and engaged as dialogue partners.

The presence of the connective actor is also crucial for the systemic designer because it helps to maintain the relation also when he/she is not physically present in the region. The systemic designer cannot stay in place for the duration of a given project, not just because of the duration required (usually more than 3 years), but because the local stakeholders must become committed to adopting the project as their own and they should take care to achieve a shared sense of sustainable rural development.

These projects are convened as real dialogue processes among actors, allowing for extensive periods of feedback and affording project change many times during the different phases of evolution (Lee et al., 2005).

Lastly, we might reflect on the role of politics in these development projects or rather the lack of political engagement. From the case studies, we can see an evident absence of politicians; it appears the rural areas are usually not a primary interest for them (the low density of population means a lot of effort for few votes). In the same way, the inhabitants of rural area feel very distant from politics, and they are quite negative about any help that they can obtain from it. With those feelings, the dialogue with the parties is very hard, and the first step for the development of those rural communities is really a bottom-up approach.

Framework

Both these theories and practices contribute to the definition of a framework for the sustainable development of rural area. The framework is made up of three steps (see Fig. 5):

1. **Analysis**: This defines the systems' boundaries and establishes the work teams in order to elaborate a double analysis (context analysis and productive activities analysis). The context analysis includes a holistic diagnosis of the local territory, society, and culture, with the goal of identifying the region's potentialities and levers for change. The productive activities analysis provides a series of criticalities that should be faced by the project.
2. **Project**: During this phase, it is essential to have a preliminary update on boundaries and work teams, because the first step can change the perspective and the priority of the development strategy to be implemented with the project. The project phase works on the output defined in step 1 (those outputs come from both local events and productive activities) in order to transform them into input

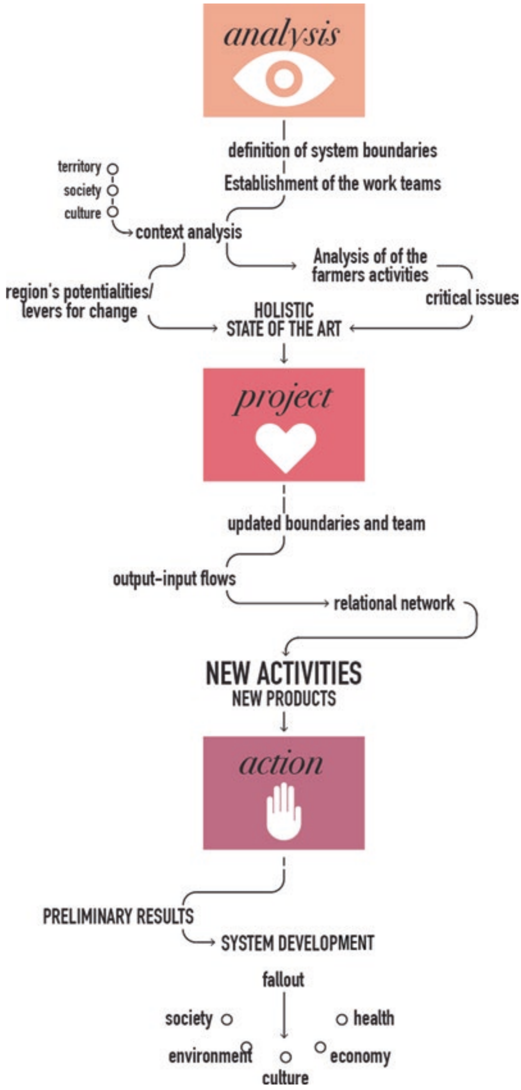

Fig. 5 Rural sustainable development framework

for other businesses already existing in the territory or that can be locally improved. The result of the project phase is the definition of new activities and products that can be developed within the area.

3. **Action**: The last step in implementing the project phase is forecasting. During this phase the first preliminary results come up and enable the flourishing of the entire complex system. The implementation of the project touches on local society, environment, culture, economy, and health.

Conclusion

Rural areas are fragile and rich, both weak and strong at the same time. They are stable, with people planted firmly in an area over generations, connected to the environment, and aware of the dependence upon it. Rural areas are often experienced as isolated and distant places from the rest of the world.

The application of SD in rural areas can guarantee the economic development of these territories thanks to the exercise of its five principles (Bistagnino, 2011):

1. **Output becomes input**: The wastes of a system become the resources of another one, in order to generate a continuous flow of material, energy, and information, leading towards zero emissions. This is the basic principle that helps anthropic processes to imitate the nature and to define new ways to pursue a sustainable development.
2. **Relations generate the system**: The different elements of a system are connected to each other from the exchange of material, energy, and information, generating the strengths of the system itself. The relationships developed within the system generate it as open and inclusive. In these rural areas, the lack of connections is a serious weakness that makes the territory very fragile, so with the increase of relations, it starts to be resilient and stronger.
3. **The system is self-generating**: The autopoietic open systems are self-supported and reproduced, so they can evolve in relation to the changes that occur in the context. Like biological systems, the system is self-regulating and dynamically stable in order to change with the co-evolution of the entire system as a whole. Rural contexts are usually very reluctant to change, however to go towards a new sustainable development they need to be flexible and adapt to new situations.
4. **Actions are local**: The operational context is prioritized, by wisely using local resources. The cultural material heritage is preserved, and any system can be identically replicated in another place. The scalability and replicability of systems are evaluated as a *unicum* (Barbero & Bicocca, 2015). As we have seen in the action cases, they are all different, one from the other, and they need distinct solutions that work just for the specific situation, which has a strong tradition and cultural heritage to preserve.
5. **Human being is at the centre of the project**: The relationship between man and context is the heart of the project, not in an anthropocentric way. The human component should be considered in the design process in order to guarantee the respect of local culture and know-how, especially in rural areas where the folklore and local culture is very vivid.

Thanks to the findings of this research, we can identify two key aspects of SD that are crucial for the economic development, especially of the rural areas: One aspect is related to the designer as mediator (Celaschi & Deserti, 2007), and the other is the common starting point from the agricultural aspects, strictly related with the consumption of food.

The important role of the designer consists in generating a trustful environment where local actors feel comfortable to actively participate in a bottom-up process of co-designing.

Agriculture is the basic activity in rural area and establishes the origin of SD projects; it is crucial to generate fruitful relations for the territory in order to identify new related business, with the use of technologies appropriate for the local know-how and possibilities. This starting point has important implications, not only economic but also health related. With a safe and devoted agriculture, the yielded food has higher quality, so primarily local people can increase their wellness.

These rural areas are characterized by high level of complexity; for that reason the SD can be able to manage a high quantity of elements that are not related to a simple and linear cause-effect relation. Some of the elements of this complexity can be found, for sure, in environment aspects: as mentioned, the prevalence of agriculture that is fragmented and for the subsistence. Other complex elements are related to the social situations: Small communities are isolated with long and strong tradition that should be valorized instead of flatten and conformed. Others are related to political aspects, where the central government is not trusted by local people that feel abandoned. This is a common feeling among people in rural areas and we need to have a methodology that enhances bottom-up processes. Inclusive design is therefore helpful to reorganize the system and define new ways for the development. Finally, as for the technology-related aspects in rural areas, there is low, if not totally absent, access to new expensive tech, so we should provide appropriate tech for each specific context (Morrison, 1983).

Merging theories and practices enables the definition of a framework that fosters sustainable development in rural areas. This entails increasing the local capacity to generate activities that create profit (growth), to act together to promote the rural area and its interactions with urban centres (inclusive), and to respect the environment (sustainable). Positive change is locally embedded, socially inclusive, and, often, producing or encompassing networks that link social scales (e.g. between local, national, and international). Good networks are inclusive, facilitating collective learning, allowing sharing of success, and generating wider social acceptance. The main outcome of this research is the definition of a framework, within a systemic design process (Bistagnino, 2011) that enables the sustainable development of rural areas and the wellness of local communities.

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Permaculture as a Systemic Design Practice

John B. Cassel and Susan V. Cousineau

Abstract Current discourse frequently situates design as a science of the artificial, but it has always been necessary to design our interaction with natural systems as well. Permaculture is a systemic design approach that aims to develop sustainable (permanent) agriculture and settlements. We present permaculture's relationship to systemic design, providing historical context to understand its ecological, agricultural, and design origins. Permaculture has made many contributions to systemic design, including simple-to-remember lists of guiding ethics and principles; a vocabulary of categories that allow the discussion of interactions; a toolbox of design methods for selecting and assembling systems of elements; overall design processes; and some agroecological and social system design insights. However, this exchange of ideas can go both ways, as there are current challenges to permaculture in which systemic design can assist, including forming stable objectives, assessing appropriate technology, stakeholder engagement, and launching viable projects. While permaculture is undertaking new developments that show progress in addressing these challenges, systemic designers can join permaculture practitioners in these efforts.

Introduction

The discourse on design has often situated it as a science of the artificial (Simon, 1996), an understandable side effect of modern needs posed by industrialization and urbanization. However, it has in fact always been necessary to design our interactions not only with modern but with natural systems as well, although this has only within the last few decades been widely acknowledged in Western society. One emerging framework for doing so is permaculture, a systemic design approach that aims to develop sustainable (*perma*nent) agriculture and settlements.

Progressively we are seeing that there are opportunities for design in natural systems (Oudolf & Kingsbury, 2013), design possibilities that break past the

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artificial dichotomy between the purely natural (public and set aside) and purely artificial (private and for singular use). In response to these opportunities, fields such as ecological engineering (Mitsch, 2012) have been developed to create more sophisticated approaches for allowing natural systems to be configured for a variety of roles and trade-offs. There can be no doubt that undertaking such a rebalancing would have impacts in the design of our systems of food production, utility provision, housing, and regional planning. Even in food production systems alone, this highlights the burgeoning need for—and reflects the current development of—both a science of agroecology (Lovell, 2012) and an agroecological engineering that applies it (Lescourret et al., 2015). If developed, an agriculture based upon perennial-based polyculture could have excellent consequences (Dewar, 2007). As these approaches rapidly gain traction and widespread support in levels from grassroots to governance, we recognize an immediate need to be developing systemic design practices that appropriately integrate their findings into society.

Given this introduction, we define permaculture and provide historical context. Next, we present permaculture's relationship to systemic design, noting particular aspects of permaculture's design approach that offer especially strong contributory potential. We then examine current challenges to which outside design practices can assist, providing a methodological approach to solving the specific challenge of shifting objectives and highlighting new developments that show progress in addressing others. Finally, we will look to future work that goes further to address the challenges we raise in participation with ongoing work in the systemic and permaculture design communities.

History and Context

From the perspective of a given individual, permaculture can be seen as a design system for ecologically responsible home economics. From a scholarly perspective, permaculture is a notoriously multi-faceted approach, evolving aggressively from its agricultural origins to culture-wide applicability by allowing shifting definitions to suit particular needs. This is an evolution it shares with the design profession. Noting the difficulty of describing what, exactly, is "permaculture," a systematic inquiry into permaculture literature (Ferguson & Lovell, 2014) describes it in its totality as "a movement, a design system, a best practices framework, and a worldview."

In a number of ways, permaculture embodies each of these facets. It is an international and regional movement of bioregional networks and itinerant teachers who disseminate and practise both design approaches and specific techniques for a variety of ecological practices. As a design system, permaculture consists of eco-design principles and spatial strategies emphasizing site specificity, synergies between components, and land use configuration in order to select and integrate practices for site- and user-specific goals. It also incorporates a best practices framework that evaluates and adopts practices for ecosystem mimicry and system optimization emphasizing perennial polycultures, integrated water management, and alternative crops. Together, these strategies serve to produce an evolving bundle of favoured practices. Permaculture generally assumes a worldview emphasizing the role of humans as ecosystem managers, encouraging volunteerism and individual action with the belief in the effectiveness and appropriateness of simple solutions.

Though permaculture's branches have flowered in many different directions, its origins and source influences are clear. Australian university lecturer Bill Mollison and undergraduate David Holmgren co-originated the concept during their academic collaboration from roughly 1976 to 1978, culminating in the publication of their notes together as *Permaculture One* (Mollison & Holmgren, 1978). The interest in the first volume took Mollison by surprise (Mollison, 1979), and he continued developing and teaching the material, leading to both the influential Permaculture Design Certificate educational programme and a massive designer's manual (Mollison, 1988). Much later, Holmgren returned to permaculture writing, producing his own foundational text (Holmgren, 2002) and other works, including some foresight regarding future trends (Holmgren, 2009).

Permaculture's source influences are worthwhile contributions in themselves and are not only directly cited but clearly visible in Mollison and Holmgren's synthesis. J. Russell Smith's *Tree Crops: A Permanent Agriculture* (Smith, 1929) proposed a similar permanent agriculture system, without the design elements, 50 years in advance. Permaculture's confidence in acting on a systemic ecological basis was directly influenced by the father of ecological engineering, Howard Odum (1971). That permaculture is formulated as a design discipline can be partially credited to Mollison's reading of Papanek (1984) and discussions with that work's author. The focus of these early permaculture writings on farm water management practices can be attributed to discussions with fellow Australian P. A. Yeomans and readings from his work (Yeomans, 1958, 1981). Masanobu Fukuoka's *One Straw Revolution* (Fukuoka, 1978) was a contemporary of *Permaculture One* and by *Permaculture Two* was already showing an influence in terms of agricultural approach, natural lifestyle, and dedication to observation, if not in terms of his anti-design philosophy. Many more ecological and design influences were observable by the time of the design manual's publication, including Lovelock (1979), Alexander, Ishikawa, and Silverstein (1977).

Over the next few years, permaculture spread quickly, due in no small part to the Permaculture Design Certificate (PDC), which delivers what Mollison considered the core material within a 72-hour course. The courses contained a viral element, such that those who went through the course were then eligible to teach the course using the same curriculum. When combined with international conferences called permaculture convergences, the PDC teaching platform spread permaculture rapidly. This format as an alternative educational programme, combined with Mollison's distaste for academia, also led to permaculture being largely rejected within conventional educational channels. The uncontrolled spread of the programme has led to other characteristics, with particular lineages of teachers adopting different areas of emphasis; notable quality problems developing from the encouragement to teach with so little training; and a variety of ad hoc quality assurance measures, including additional teaching programmes and credentials (such as Gaia University and the Permaculture Research Institute). Given the limitations of the PDC format, and individual biases and experience of trainers, practitioners often take multiple PDCs with different "genealogies" to enrich their understanding, develop a broader perspective, and combat potential quality issues. Furthermore, there has been an explosive proliferation of more focused, often hands-on workshops to augment the basic offerings within the 72-hour design course. These workshops in and of themselves offer PDC graduates multiple avenues through which to further develop their skills, knowledge, and experience and tailor their education to their own personalized goals.

Though the initial permaculture works and teachings were developed in Australia and often dismissed as being somewhat limited to tropical and subtropical climates, an increasing number of practitioners have focused on developing systems and educational material to colder climates, including North America and Europe (Falk, 2013; Hemenway, 2009; Holzer, 2011; Jacke & Toensmeier, 2005a, 2005b; Shepard, 2013; Whitefield, 2005). Some of these works mention following on from the forest gardening tradition of Robert Hart and Martin Crawford in England. The genesis of written material in permaculture has been spreading further geographically, with 49% from Oceania (Australia and New Zealand) and 41% North America in 1978 through 1987 to 43% from North America, 34% Europe, 9% Oceania, 6% Africa, and 9% Asia in 2008 through 2013 (Ferguson & Lovell, 2014). In addition to widespread print resources, the permaculture community takes full advantage of contemporary communications approaches with websites, online videos, and podcasts. It seems very likely that given the priority that permaculture gives to existing indigenous agroecological lifeways, permaculture-compatible practices will continue to spread both in practice and in available information.

Particularly in Western countries, including Western Europe, the United Kingdom, and North America, permaculture's contributions to designing systems for urban and suburban life have been significant (Hemenway, 2015). Within this area there has been a strong element of and particular interest in political and social action. The diversity of permaculture practice is illustrated by comparing two very different notable movements: Transition Towns (Hopkins, 2008) and Food Not Lawns (Flores, 2006). Transition Towns is a movement of civic organization aimed at creating municipally accepted comprehensive plans for transitioning to localized and resilient low-energy operations by means of mobilization, dialogue, retraining, and organizational design. The relationship between the Transition Town movement and permaculture is very subtle: It is presented briefly as the idea behind the idea and borrows freely from the design methods toolbox, but it would be entirely possible to participate in the transition movement and not know or care of permaculture. On the other hand, Food Not Lawns maintains a clear association with permaculture, effectively incorporating its design framework for the urban context. In their work, Food Not Lawns encourages the conversion of lawns to gardens and related community-building activities such as seed and harvest sharing. With strong personal and social appeal within movements such as these, and a substantial readership, permaculture maintains a viable and rapidly growing public interest.

Permaculture Practitioners as Systemic Designers

Before making the claim that permaculture practitioners are systemic designers, we need to make clear what designers are—and then, specifically, what systemic designers are. For our purposes, design is the redirection of attention through considered affordances and communications.

> Systemic design is distinguished from service or experience design in terms of scale, social complexity and integration – it is concerned with higher order systems that entail multiple subsystems. By integrating systems thinking and its methods, systemic design brings human-centred design to complex, multi-stakeholder service systems. It adapts from known design competencies – form and process reasoning, social and generative research methods, and sketching and visualization practices – to describe, map, propose and reconfigure complex services and systems. (SDRN, 2016)

There are several ways that permaculture qualifies as a contemporary design practice. Specific to the direction of this paper, permaculture has shared many of the same evolutionary steps and shows many parallels with the practices of design in general and to that of systemic design in particular.

First, permaculture arranges its training and professional activity in a way similar to design. Permaculture practitioners have similar professional paths to traditionally recognized designers. Those interested in permaculture obtain one or more certificates in permaculture design consisting of a brief introduction to both theory and practice. They then engage in a series of apprenticeships and volunteer projects in developing sites, before finally engaging in design services.

Second, permaculture practitioners undertake design processes, engaging in a period of goal discovery and analysis prior to action, encouraging prototypes, experimentation, and local adaptation. Permaculture practitioners undertake design processes and have specific design methods used to develop questions discovered in those processes. These design methods will be immediately familiar as spanning the variety of design research approaches and include observation, ethnography, functional design, analysis, dialogue and group facilitation, foresight scenarios, diagramming, random combinations, sketching, and so forth (Falk, 2013; Flores, 2006; Holmgren, 2009; Hopkins, 2008; Mollison, 1988). As in the design profession, there is a great deal of variation in the degree of training participants have in the design research methods they utilize, and there is less usage of design research methods than problems might call for.

Also, in its relationships to traditional science, permaculture has shown many of the same tensions that emerge in the design literature. Permaculture has both internal and external dialogues about how scientific it is supposed to be and its relation to the scientific community (Ferguson, 2014a, 2014b; Ferguson & Lovell, 2014). These debates suggest that permaculture is best described as a design practice, which is neither science nor humanity but an application of the two into a third discipline that provides appropriate solutions to particular problems (Cross, 1982). This may be achieved through a careful balance of scientific application, development of participant subjectivities, and single-case problem-solving.

Perhaps more than any other criteria, permaculture is a systemic design practice because it provides practices for people to design positive and meaningful roles for themselves in systems. Following Raymond Loewy's *Most Advanced Yet Acceptable* (Sterling, 2005) motto, to be "advanced" is to both steward an ecosystem and provide for one's own needs, the needs of one's family, and the needs of the community and consume no more than necessary to maintain that state of affairs. Recognizing the need for acceptability has perhaps been longer coming, but can readily be seen in the community and civic organization elements of recent permaculture works. This acceptability does not necessarily mean watering down what the design system may change, but it does call for that change to be justified in demonstrated benefits, ultimately appealing better to those whom are called to adopt those designs.

Finally, when we review permaculture's contributions, each reader may be able to observe further parallels to their practice of systemic design.

Contributions of Permaculture Design

The early days of permaculture have provided many of the developmental and foundational materials that continue to have a strong influence on its development and practice today. The entire body of works defining, describing, and informing the practice of permaculture is widely disperse and, reflecting its origins as a popular movement, has mostly developed not through academic literature, but instead through books, magazines, courses, conferences, and projects. It is apparent, however, that with so many people trying to work systemically, permaculture has made a number of contributions to systemic design. The most notably visible influence in permaculture has been *Permaculture: A Designer's Manual* (Mollison, 1988), hereafter abbreviated as PDM. Though greatly respected for its original influence, other works have since displaced it for many in terms of both carefully stating principles and leading to demonstrable outcomes (Hemenway, 2009; Holmgren, 2002, 2009; Holzer, 2011; Jacke & Toensmeier, 2005b; Whitefield, 2005). Nonetheless, in terms of its scope and general content, the PDM remains a suitable overview to the core concepts and processes of permaculture.

Permaculture starts from a simple set of guiding ethics that both suggest and help evaluate potential designs, filtering all that is to follow. Understanding permaculture's terminology and how it frames the contents of its design stages a brief overview of permaculture's analytical methods. When coupled with knowledge of common design patterns, this builds a progression from patterns to details that helps to assure appropriate techniques are used when developing systems. Finally, we briefly highlight a few of the specific insights permaculture may offer in designing agroecological and socioeconomic systems.

Ethics

> Although [permaculture] is about design, it is also about values and ethics, and above all else about a sense of personal responsibility for earth care. (Mollison, 1988, p.1)

From the start, Mollison and Holmgren sought to establish permaculture as a discipline in which any particular methods or processes are only appropriately employed in the context of right means and outcome. The first page of the PDM lays out the prime directive of permaculture: "The only ethical decision is to take responsibility for our own existence and that of our children" (p.1). As such, permaculture addresses ethics rather differently than other design approaches. While some may feel that ethics really only manifest in practice, permaculture starts with clear declarations of principles. This clarity allows design alternatives to be settled by a common appeal to those aspects that practitioners feel really matter, as opposed to which stemming from the use of a certain technique or appeal to personal preference. In other words, the explicit foundation of permaculture practice and design upon a core set of ethics serves to help people reconsider their perceived needs, rather than just accommodate them. A clear ethical stance also acts to delimit the permaculture design community, actively fostering an environment of design that seeks to satisfy multiple, rather than singular or isolated, objectives.

In the PDM, these ethics are clearly articulated in The Ethical Basis of Permaculture as follows:

1. *Care of the Earth*: Provision for all life systems to continue and multiply.
2. *Care of People*: Provision for people to access those resources necessary to their existence.
3. *Setting Limits to Population and Consumption*: By governing our own needs, we can set resources aside to further the above principles.

Of these, the third point has not been universally adopted by the permaculture community. For example, *Gaia's Garden* (Hemenway, 2009) lists the three ethics as "caring for Earth, caring for people, and reinvesting the surplus that this care will create." One occasionally hears the abbreviated "Earth care, people care, fair share," further developing the ambiguity between only taking one's fair share and sharing as to produce a communal use of resources. The first two points seem to be uncontroversial in the permaculture community.

How is it that permaculture might have specific, agreed-upon ethical precepts when design disciplines, such as industrial design, graphic design, or interaction design, do not? It may be that to think of permaculture as such a design discipline is a category error, as some permaculture teachers prefer the approach to be known a "toolbox" rather than the specific set of techniques of any domain. These ethics then form criteria for which tools are appropriate to bring to a particular task. In this way, permaculture might be better thought of as a design paradigm instead of a design discipline, in the same way that systemic design also engages ethical foundations.

The overall effect of stating ethics first is to provide a final assessment that trumps either process or technique, seemingly giving permaculture a consequentialist flavour. However, how do we know we are meeting these ethics? We need a basic idea of what flourishing looks like for the earth and people to properly care for it, which we can develop through further principles and structured through terminology.

Design Principles and Vocabulary

Permaculture design, particularly in terms of vocabulary, is undergoing a transition from being very specific about landscape configuration to a much more general usage. Where permaculture terms such as "zone" and "sector" initially referred to geographic regions within a property, the community is finding these terms designate much more general concepts. As a result of this development, there is a gap in graphic design tools between the existing cartographic representations for the spatial extent described by these terms and graphical conventions for working with their general meanings in a diagrammatic way. This gap presents design researchers a new area to develop novel forms of visual communication and diagrammatic processes.

A design element is any discrete part that can be selected to play a role in the designed system, whether a plant, animal, person, structure, room, soil, landscape feature, or organization. Permaculture design involves arranging these design elements structurally and temporally into functional interrelationships, looking to make sure that outputs become inputs, problems become solutions, necessary functions are provided for redundantly, and whenever possible elements have multiple functional uses. These interrelationships are developed with attention to beneficial, neutral, and detrimental interactions. Individual elements are subject to contextual factors that constrain their appropriate place within the design. The overall objective of such arrangements is to produce yield or surplus over self-sufficiency of the system itself. Yield is understood not only in terms of the amounts of products produced but also as any energy produced, captured, stored, conserved, or converted by the system.

Ongoing systemic yields are maintained through attention to the nature of resources used. Highest preference is given to resources that increase with modest use, those unaffected by use, and those that disappear or degrade if not used. Caution is encouraged in depending on those that are reduced by use, and prohibitions are recommended against using resources which pollute or destroy other resources. Therefore, maintaining cycles is a key means of stewarding resources, with every link in a cycle constituting further yield. "Cycles in nature are diversion routes away from entropic ends – life itself cycles nutrients – giving opportunities for yield, and thus opportunities for species to occupy time niches" (Mollison, 1988).

The appropriate placement of elements is not only determined by their interrelationships but how they fit holistically into the designed system. "Zones" and "sectors" are two designations for helping determine this fit. PDM introduces zones and sectors with respect to permaculture's orientation to managing energy resources and cycles in a broad sense: The zones establish the flow of energies in the system, while sectors establish the flow of energies through the system.

The primary resources that zones manage are the energy and attention of the designer. Zones are clusters of design elements that take similar levels of attention or are best attended to together. Until recently, these zones were conceptually limited to regions of a landscape, biasing placing the higher effort subsystems closer to residences, access routes, and other areas of frequent traffic. Zones are traditionally numbered one through five, with one indicating very frequent interaction and five indicating that it is better for the system to proceed without any intervention from the designer.

Here is an example when the system of zones is used for designing the spatial layout of a homestead:

- Zone 1: Elements to be placed near the immediate household as they require close observation, frequent visits, or daily work input, producing daily yields. These elements typically require at least one daily visit to manage them.
- Zone 2: Elements to be placed reasonably close as to be considered ready for domestic consumption, such as further built infrastructure, household services requiring less tending, and physical features which protect and provide for the residence. The required management attention may range from once daily to weekly.
- Zone 3: Commercial crops and field shelters, feed stores, and silos. The management attention needed ranges from weekly to every few months.
- Zone 4: Areas that are transitional to wilderness, often woodlands, for fuel, infrastructure, forage, and recreation. These require management attention only a few times a year.
- Zone 5: Wilderness, which is not to be called upon except in emergencies, but to be explored for ideas. Management attention is not to be applied.

Today, permaculture designers employ formulations of zones that transcend physical arrangement. For example, when considering personal interactions in a phase in a project, we might say that a person we work with every day would be in Zone 1, while somebody who might only see the final presentation could be in Zone 4. As another example, an urban person unable to grow their own food might consider their neighbours with gardens a primary resource (e.g. Zone 2), but also attend local farmer's markets (Zone 3), less regularly acquire bulk orders from a local food cooperative (Zone 4), and ideally only have to visit conventional markets under rare circumstances (Zone 5).

Unlike zones, sectors refer to flows from outside of the designed system, designating a particular set of external factors. Depending upon their location within the structure of relationships, different elements might be impacted differently by sectors, and we want to locate those elements as to react most favourably to those conditions. For example, we might wish to place plants near the street if they are tall as to provide a buffer for sound and can accumulate lead or other potential chemicals from the soil near roadways but are meant for purposes other than human consumption, for example, sunflowers. We might locate friendly people and those who can easily tolerate distractions near the door in an office. In general, the mapping of sectors is used to indicate particular wind corridors, seasonal sun angles, sight-lines to neighbour properties, wildlife corridors, and other influences impacting the household by given directions. More recently, sectors include not only natural relationships but also social factors, local regulations and governance, and market opportunities (Hemenway, 2015). Given this expansion, we observe that individual sectors can also change over time, highlighting the necessity of ongoing design processes and adaptive management for optimal site outcomes.

A known set of elements working together functionally, with connected output-to-input relationships and no undermining detrimental interactions, suitable to particular conditions, is called a "guild" in the permaculture literature. However, "guild" is a particularly unfortunate choice as that term means precisely the opposite in ecology, referring to a group of organisms that share the same niche and are likely, at least in theory, to compete with one another. We suggest the word "team" implies the underlying concept much better. Setting aside for a moment conflicts in terminology, the concept describes a group of elements that serve each other functionally and belong in different niches. One important category of niches for agro-ecological purposes is layers which explain how different plants can accommodate each other spatially: rooting plants, ground covers, mushrooms and other fungi, small plants such as herbs and vegetables, shrubs, small trees, large trees, vines, and water plants. The idea of niche suitably applies outside of ecology as well, such as in reference to workers who may take different shifts or who have a unique set of skills to offer the team.

Permaculture Design Methods

Permaculture allows for a broad methodological permissiveness. In the PDM, suggested methodologies include improving tools; collecting a large set of observations, insights ("Eureka moments"), and trials; guessing; responding with close attention to unique or strange events; and being open to accident, imitation, patterning, and constant adjustment to feedback. Design techniques commonly include observation, flow diagrams, biomimicry, decision planning using both forward and backward steps, and making maps with overlays. However, there is a body of approaches that characteristically defines the analytical side of permaculture methods, namely, the arrangement of elements within a system so as to fulfil the various requirements, opportunities, and limitations of discovered zones and sectors. This body of methods is systematically aimed at reducing external inputs, wastes, and unnecessary work by assembling necessary elements together. We will see that this analytical permaculture is a process of cycles of open discovery directed to building processes of closed material cycles.

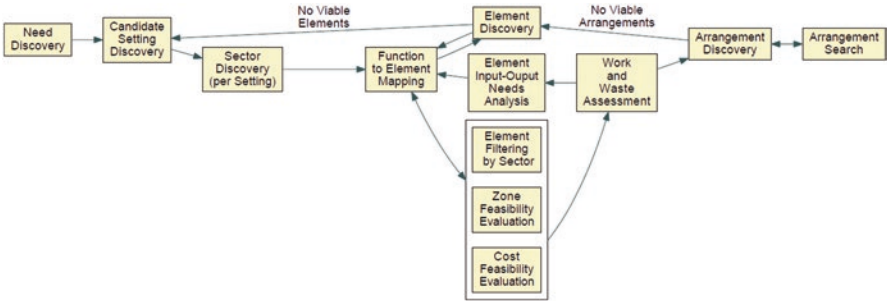

Fig. 1 Permaculture's analysis process

When a permaculture design can speak entirely in terms of networks of functionality and need, and then later determine the elements to meet those needs by considering the sectors, layers, and zones, we've encountered a working example of the permaculture design dictate to work "from patterns to details." This is effectively the engineering design approach of determining sequences of functions and flows and then inferring designs with function/component matrices (Bryant, Stone, McAdams, Kutoglu, & Campbell, 2005; Hirtz, Stone, McAdams, Szykman, & Wood, 2002).

We can formalize this analytical phase of permaculture as a series of steps (see Fig. 1) constituting a systematic process. As an input to the analysis, we need to undertake the following discovery steps, which can be handled with any number of design methods as part of the overall permaculture process, described later.

Need Discovery

We start from needs, itemizing an initial set of required functions, such as to satisfy the needs of the people intending to live on a property. Given the nature of permaculture, by default these needs are the household needs of the individual designer, though they can be any observed need. A wide range of ethnographic and interviewing methods are appropriate to this discovery, as well as checklists of common needs.

Setting and Sector Discovery

Given these initial needs, research various ecological, built, and social structures that may meet these needs. The places or situations in which these structures might be viable are settings which form the basis for further examination. Use the needs and this initial research to produce a variety of settings. More settings might need to be discovered should those initially provided not prove viable. For each potentially viable setting, we determine its sectors. Carefully consider all stakeholders, including natural stakeholders, at this phase.

With an initial set of needs, settings, and sectors discovered, we are prepared to begin the more analytical stage of this process.

Function to Element Mapping

For each function, select candidate elements or systems that can undertake processing, production, or maintenance to meet needs.

Element Discovery

For each function, research different ways it could be satisfied, consulting the literature, experts, and checklists, as well as undertaking generative exercises.

Sector, Zone, and Cost Feasibility

After finding a candidate set of elements, it is good to check if they are feasible. One way a system might not be viable is if it requires too much work to maintain. One way to assess if a system has too much work is to estimate the interaction requirements of each element and assign them to zones. With an estimate of the time available to each zone, we can disqualify the system if it has too many elements for that zone. Another means of disqualification is if an element is inappropriate to a sector. Finally, disqualify systems by initial cost, and it should also be filtered by all appropriate standards. This filtering can be deferred within the search loop described later, with a trade-off between elaborating systems that are not viable and the cost of evaluating viability.

Work and Waste Analysis

This is where the design process described uniquely belongs to permaculture, attempting to assure that all of the design elements work together cyclically. At this point, we want to detect external inputs, waste creation, and avoidable work, seeing if those needs should be accounted for. If it is feasible to do better, then we proceed to expand the list of needs. Otherwise, we have found the candidate parts of the system. One thing to remember is that this design process can be undertaken iteratively and it is good to extend an imperfect system outward rather than be overwhelmed trying to manage a larger and more elaborate system with unforeseen complications.

Element Input-Output Needs Analysis

If a candidate system has too many unmet needs, but still seems viable so far, we continue iteratively by finding elements that meet these unsatisfied needs. We find potential additional elements that satisfy the needs of the initial set. We try each of these in turn by order of apparent promise, observing the new set of needs added by the new elements.

Overall, the right way to think of the cycle of function mapping, feasibility evaluation, work/waste assessment, and element I/O need analysis is as a search tree of candidates. Each set of elements that could satisfy the initial needs is a starting point, but these elements may generate needs of their own, requiring a new set of elements to satisfy those needs, and so on until either the work and waste required is low enough or we run out of feasible elements to add. However, this is a search tree of a peculiar kind, in that we could attempt to discover more elements to add to it as any potential need can motivate research for new elements and any particular element can motivate research for potential needs and compatible teams. For this reason, this method of permaculture design is one of a few analytical techniques prepared to reckon with the unbounded character of real problems (Cassel, 2014).

The result of this cycle is a candidate set of elements for a given setting or property, each vetted to meet the initial needs and satisfy the existing sectors and designed to be part of a system of mutual relationships. We next want to see if they are logistically feasible. It is insufficient to have input/output relationships abstractly satisfied; they must be arranged and sequenced correctly in space and time. To do this, we start the assembly step, which itself has a discovery phase followed by a layout phase.

Arrangement Discovery

The purpose of the discovery phase is to be sure that we have a good number of potential arrangements in case a desirable arrangement is hard to find. To discover these arrangements, PDM suggests we first try some random assemblies. In order to do this, we list out all of the elements which we are aware and then try randomly joining them with connective phrases such as “interacts with.” If the arrangement is spatial, we can use connectives such as “attached to,” “beside,” “around,” “under,” “containing,” etc. In addition to mere structural descriptions of possibilities, it would be possible to undertake a more directed version of the random assembly process by including functional phrases, such as “moderates the temperature of” or “fertilize,” which may suggest particularly effective relationships usable in the layout phase.

Arrangement Search

Establish layout of element relationships using heuristics for increased efficiency, reduced travel time or required labour, waste reduction, and other criteria (Flores, 2006). Similar to matrix-based engineering design activities (Eppinger & Browning, 2012), a matrix between elements can help determine complementary proximities and necessary separations, establishing the feasibility of particular arrangements. Overlays on a base map are helpful in experimenting with proposed layouts and ensuring that spatial requirements are met. Similarly, cut-outs for individual elements allow for movement into different positions, as though fitting a puzzle. Both strategies often suggest unexpected opportunities for placements and potentially additional relationships. Consider also arrangements over time. If no arrangements are discovered, a different set of elements may be required.

Overall, this process highlights that permaculture has several common analytical steps that work together cohesively.

A Permaculture Design Process

As PDM was very spare in specifying any overall design process, many formulations for the permaculture design process as a whole have been developed. As one of the many potential examples, Flores (2006) provides a systemic process compatible with many permaculture activities that strikes a good balance between simplicity and realism.

1. *Undertake deep observation*: Start with observation of every relevant facet, including resources to be stewarded, present situation, and how various stakeholders, including the designer, currently live and feel about their situation. Take existing and potential ecosystem actors into account.
2. *Determine initial underlying goals and needs (with priorities)*: At the point of deciding that something will be done, it is good to begin by stating what the desired end result will be. As with all design, these goals can be the subject of iteration given experience, but it's good to have one pass at stating what is wanted without reference to any particular solution and develop an understanding of what does and does not constitute reasonable compromises or correct functioning.
3. *Observe with purpose*: With some goals at hand, we can start to observe the subject of those goals. Ideally, this observation takes place over the characteristic length of the subject, such as a growing season. At this point, it is useful to start forming potential ideas for designs and developing potential goals around the completion of particular solutions. Sketch potential ideas.
4. *Determine boundaries*: Understanding the boundaries of a project means attention to physical, legal, political, social, and personal boundaries. If the work involves a spatial extent, build a base map. Understand existing regulation.

Consider how the work will be undertaken, including when it will take place, with whom, for how long, with what provisions for rest, under which conditions the project will be stopped, what personal resources are available, and what limits exist. Research neighbours or other stakeholders who may have conflicting interests and think through how to handle potential resistance.

5. *Inventory available resources*: Designate the zones and sectors imposed by the situation. List out all elements directly available and examine their relevant conditions. If undertaking a project with spatial extent, produce an overlay of existing elements. If materials are to be purchased, list candidates with their costs and comparative attributes.
6. *Undertake analysis for placement and strategy*: This analysis was described above in detail in the design methods section.

Ecological Design

From a physical design standpoint, the practice of ecological design and permaculture is based on very similar principles, objectives, and practices. Ecological design practices comprise the bulk of permaculture content and materials, in terms of instruction in ecological relationships between elements, biological bases for decision-making, and understanding of the relevance of ecological patterning in design (Benyus, 2002). Permaculture's unique contribution lies in holistically considering both the physical elements of a site in addition to its social and economic elements. While ecological design may incorporate or adjust for these factors, it is not de facto based on an ethical foundation, as is permaculture. This explicit "human habitat" factor has likely been a large contributor to the widespread uptake and popularity of the permaculture concept, particularly for communities and small groups seeking to form living structures, such as ecovillages.

Examples of natural patterns referenced in both the ecological design and permaculture literature include fractals, spirals, tori, and dendritic branching, which are widely observable in nature in growth and flow patterns, demographies of species populations, and the geometry of structures lending aspects such as strength or flexibility. The observed ecological pattern of increased productivity at the edge between two systems, such as between land and water, informs how we might increase productivity by changing the edge characteristics of elements we design into our landscapes. A popular example is the replacement of circular or rectilinear ponds with irregularly shaped ponds that follow landscape contours, increasing edge length using convolutions to create a variety of microhabitats within pockets and peninsulas. Similarly, the use of branching "keyhole" paths can maximize the amount of planting area per unit of access path. Edge is an attribute to be controlled but not necessarily maximized, as fragments of ecosystems can have a radically different character than those maintained cohesively (Jacke & Toensmeier, 2005b).

In a social context, these patterns can also be present in traditions. Practices that encode knowledge in stories, dance, designs, and other embodied cultural elements can retain as much appropriate advice as being aware of a natural pattern. Certainly, close relationships between natural and cultural patterns are fundamental within many indigenous societies.

The broader systemic concept of a scale of permanence is cited in Yeomans's works and has been subsequently carried through into contemporary permaculture literature and teaching (Yeomans, 1958). The concept is roughly similar to Stewart Brand's more recent adaptation of shearing layers (Brand, 1995), itself based on ecological and systems theory ideas from a similar period. Yeomans's idea was to systematize how the relative permanence of site factors determined their priority during the design process. The scale of permanence he posed for the farm was from longest to shortest: climate, landscape, water supply, roads/access, trees, structures, subdivision fences, and soil. Similarly, the Regrarians Platform (Doherty & Heenan, 2016) teaches broad acre design from the scale of permanence defined by climate, geography, water, access, forestry, buildings, fencing, soils, economy, and energy. It is worth noting that in these generalized frameworks, and contrary to many traditional soil scientists and geologists, soil is understood as capable of being both destroyed and built surprisingly quickly given proper management.

The scale of permanence concept has also been adapted into applications for social permaculture, which we consider in the following section.

Socioeconomic Practices

Having developed permaculture's foundation in a system of ethics, Mollison directly addresses socioeconomics in the PDM chapter "Strategies for an Alternative Nation." In this he treats social organization in a structural sense, as though societies could be arranged schematically. He describes an alternative United Nations of bioregional organizations, which themselves consist of both traditional and selected extended family arrangements. These organizations are supported through trusts and similar legal strategies. Bioregional groups support the development of villages formed with the purpose of offering services, such as community energy initiatives, employment offices, and recycling collection. The bioregions ideally group their resources to make profitable investments but go through filters to avoid sponsoring activities not in line with the ethics. These organizations should pay attention to future trends, such as deforestation, rising sea levels due to climate change, and the patenting of seeds and other natural resources, in order to take mitigating action. Aid reform is another consideration addressed, with an emphasis on locally appropriate solutions and a lack of dependency on development as an aid consideration.

A primary criticism of Mollison's work is that it has offered relatively little advice on the process of how to transition into these structures or even into permaculture more generally. Indeed, the first years following publication of the PDM in 1988 saw comparatively little social permaculture work. However, in the last two decades, there has been an increasing emphasis on the interpersonal, and even intrapersonal, aspects of permaculture, as observed in media venues such as The

Permaculture Podcast. Rob Hopkins's work in developing the Transition Towns model is a primary example. *The Transition Handbook* (Hopkins, 2008) offers a model, developed through the genesis and progress of real projects, for designing transitions towards a low-energy economy. While developed without express reference to permaculture foundations, clear parallels in ethics and methodology, particularly in its holistic perspective, are immediately apparent. The Transition Towns framework includes a long development period of raising awareness and interest before announcing formal initiatives; advice for working with local and regional government; and developing community-led context through various collaborative design methods, such as the World Cafe and Open Space methods. Importantly, it provides guidelines for creating transition plans for leadership so that those who have served strongly in one stage can simply participate in other stages. This avoids coupling transitions to particular strong personalities and provides a more robust community backing by retaining existing members with skills likely to be relevant to the site or situation during transition. The book also offers a great deal of advice and frameworking useful to personal transitions.

The relatively recent resurgence of social permaculture in published materials (Flores, 2006; Hemenway, 2015; Trought, 2015) suggests permaculture's previous social contributions are starting points from which further methodological and philosophical evolution is rapidly occurring. One example of social methodological development in the community is that the scale of permanence has been adapted into a broader tool that looks at the malleability of phenomenon on one hand and the permanence of the effect on the other. One such application is categorizing the ongoing effect of different stakeholder groups around a particular issue relative to their difficulty to mobilize. For example, it may be easy to get university students excited about a particular issue, but their mobilization may be of limited time and influence. On the other hand, administrators who have seen many trends come and go might be slower to adopt new practices, but have long-lasting influence in what they do pursue. In the context of permaculture education, this type of analysis suggests that permaculture may be easier to introduce at the secondary school level than in higher education (Bertrando, 2015).

Systemic Challenges to Permaculture

Though permaculture's combination of clear ethics, design methods, agroecological best practices, and viral distribution mechanisms lends it great potential to be a powerful force for change, no human endeavour is perfect, and permaculture faces many challenges (Ferguson, 2014b; Mann, 2015; Scott, 2010). Some areas where system designers may offer advice and assistance include technology assessment, stakeholder engagement, clarifying conflicting requirements, deployment logistics, project modelling, and information technology. This paper will take a deep look at shifting and conflicting requirements, establishing a taxonomy of objectives that fits with permaculture's systemic approach.

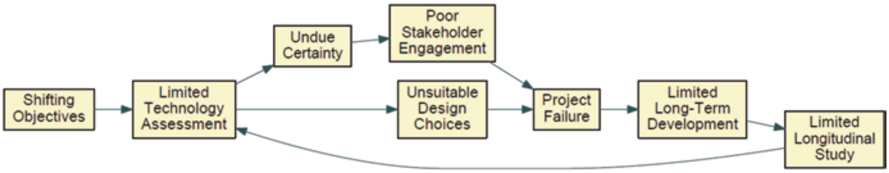

Fig. 2 Permaculture's systemic challenges

Let us take a moment to summarize what these issues are and how they are systemically related to each other (see Fig. 2). The broad number of potential objectives for permaculture designs often leads to mid-process shifts in exactly which objectives are being pursued. Among other complications, this can lead to problems of technology assessment or knowing which techniques and arrangements might have appropriate consequences. A design created from an unstable array of objectives, particularly when coupled with an ethical certainty in the appropriateness of the selected approach, can lead to unfortunate outcomes in engaging other stakeholders, such as neglecting the preference of critical partners or alienating supporters with vicissitude in direction. Many projects succumb to this combination of poor social engagement and mistaken use of technique, producing results that lack ecological, economic, or social viability. Overall, the lack of successful and established projects erodes the capability to harvest permaculture's perennial yields and set down regional roots. Regional institutions are necessary for establishing distribution chains and taking on longer-term ecological goals such as developing regionally appropriate varieties, which are further undermined by the aforementioned lack of adequate technology assessment.

Among the systemic problems permaculture faces, that of shifting objectives seems to be a root issue. Objectives shift when they are added and removed in an ad hoc way during a design's evaluation, leading to some approach seeming like it is better while it actually meets the desired intentions poorly. In addition to rejecting some alternatives due to an ad hoc subset of the overall criteria, there is a danger in trying to make arguments for substitutions or proposed alternatives based on objectives that are actually poor stand-ins for other criteria. For example, in terms of agricultural yield, we might see pounds per acre per energy input reported in one work, while another might report calories per acre per dollar. Both are proxies for the needed ongoing nutritional contribution of the yield undertaken as to be maximally effective at using resources. What we would like to do is better organize objectives in a way compatible with permaculture's approach.

What we will see is that the definitions of permaculture can focus or constrain the way objectives are formulated, allowing them to be clearly differentiated. Indeed, the ethics, principles, and corresponding forms of analysis lead to objectives having a particular form. Let's start by defining objectives and figuring out what kinds of objectives we might support.

An objective is the commitment that by some particular criteria conditions are defined to be improved should some facet be made present, absent, greater, lesser, or closer to a particular. These criteria designate a particular scope, such that two objectives with different criteria might not have any clear way of determining an appropriate trade-off between them. There are two different kinds of objectives: constraints and goals. We are obliged to meet, remove, or modify constraints, or we cannot go forward. A particular design fails an economic constraint if we cannot summon the labour, capital, or resources to implement it. For a goal, the closer we get to some target amount, the better things are perceived to be. This claim requires a closer examination than the feasibility claim to evaluate its veracity. In short, one can pursue different goals at the expense of others, but one cannot pursue different constraints. We say a constraint is active in a particular system if it is limiting any improvement in goal performance.

Given the expansiveness of the ethics, where can we begin? To start, let us partition objectives by their scope into why, what, and how. Said differently, we are after "grand strategic," "strategic," and "tactical" objectives (Tow, 2003). Some permaculture designers refer to these as values, goals, and criteria (Jacke & Toensmeier, 2005a), but these terms are defined differently here. This will let us temporarily defer relevant tactical objectives such as "20 bushels of apples per year" until we have the information architecture to maintain them and assess their appropriateness.

Given this, we are after a statement of grand strategy that establishes why we adopt some objectives and not others. Overall, we want a grand strategy that embraces the conceptual work already done by permaculture: the assembly of elements into arrangements that meet previously identified needs of the site and its resource managers and provide additional yields continually by means of arranging cycles for processing all wastes and reducing required inputs.

Therefore, a viable grand strategy for permaculture is to maximize the sustained flourishing of the resource-renewing cycles in which we participate. This strategy articulates both care for the environment that supports our continued survival and the necessity of a human role in that care. It does not neglect education or traditions, but recognizes that human development is vital to our ongoing participation. It also leaves out a variety of contemporary activities that we might care for ourselves better without. From this strategy of sustaining resource-renewing cycles, we can identify three other key strategic goals: directly fostering renewing cycles, minimizing activities that disrupt those cycles, and minimizing dependencies outside of those cycles. Even at this degree of abstraction, we have a useful conflict between applying external resources to the first two for short-term growth and not utilizing external resources to satisfy the third, for long-term stability.

How do we approach these cycles strategically? To maintain our households and take responsibility for our lives, we should start with the cycles we have no choice but to be a part of. The cycles of highest priority are those of oxygen/carbon dioxide, water and food/effluent, clothing and shelter/spent fuel, and worn fibres.

Given that a core need is establishing cyclic biological cycles for food and energy, let us look at some of the strategic objectives that growers, broadly understood, might have. Growers could be interested in having enough good food at any particular time, and developing plant and soil life to assure that remains the case, establishing water resource security; capturing carbon; engaging in healthy outdoor activity; being productively and personally engaged with both human and non-human others; engaging in exchange (including economic exchange); producing fibres, shelter materials, and medicines; and acquiring and maintaining tools.

Talking about our role in cycles allows us to categorize goals analytically. When attempting to design a section of any particular cycle, we can see that we're either talking about producing an input, processing an output, maintaining the character of a linkage, or some combination of these. We should see that this analytical breakdown of objectives is the same as permaculture's analysis of systems, which looks to introduce elements that process undue surpluses or produce inputs that are lacking while still maintaining needed yields.

First, let us look at some ways to consider gross yield or total outputs. The simplest thing to do is simply to put what one harvests on a scale and measure the pounds of yield. However, with a holistic perspective, simple yield becomes only a crude proxy for an end goal of a self-regenerating, highly integrated system. It would be slightly better to measure pounds of consumable food, but what we're really after is human use of the yield. A different place to begin is the calories produced, and perhaps only the human-consumable calories, though fuel yields may also be desirable. A more nuanced choice of objective would look to a balanced full-spectrum analysis of human nutrition and hydration. This means that litres of potable water captured might be an important objective in its own right. Of course, over the scale of a lifetime, we often need something more than our daily meals, so medicine per related human medical incident is also an important objective (although much more difficult to measure in any comparable sense, particularly given that this kind of design might change one's lifestyle in a medically significant way).

Some sectors have a greater capability for particular yields compared to others, and even within sectors certain teams lead to particular advantages with respect to some nutrients compared to others. Both of these factors lead to advantages in trade and exchange. Given this, we are interested in full-spectrum cross-resource yields on average across systems: A given acre producing a wide spectrum of yields might not be better than a number of more specialized systems even discounting for transportation needs. We can look at the current market value of the yield as one proxy, while looking at historical prices might give another. Historical prices reflect different trade-offs based on, among other things, a different ability to tap into energy resources that may reflect future constraints. Overall, it is a useful restriction to not see profit as an objective in itself but as a mechanism to input resources for further objectives, as well as a measure of robustness to change. In any case, we have to presume the value or cost in dollars of any particular yield or input will change as conditions change across the time by which the objective is evaluated.

Another gross yield is the capacity to process inputs that otherwise would be wastes. At the boundary between agricultural yields and other systems, we might want to remediate various pollution issues. Another powerful objective—one with increasing potential as a measurable financial profit—is to store carbon as organic matter in the soil, plant, and fungi instead of in the atmosphere.

A final kind of gross yield measures how well a diversity of cycles is maintained, as measured by the populations of particular species, acres of particular ecosystems, or people engaged in particular regional livelihoods. These numbers both have intrinsic merit and may serve as relatively short-term proxies of longer-term performance in other objectives.

This section presents the need for addressing multipurpose objectives and using different metrics to measure progress towards those objectives: likely to be a part of, but not necessary for, systemic design.

We've now considered some gross yields and will next consider the modifications to net yields by looking at the denominator appropriate to each. Each of the above is clearly per unit of comparable land (e.g. per acre) and over a given period of time (e.g. per year). Often, the active constraint is human labour available, so per person engaged actively in the ecosystem is a potentially important criterion. Energy is also an important consideration and commonly considered in terms of units of energy, such as fuel or joules, spent in production, processing, and distribution.

When considering any particular mix of net yields, we will need to qualify the period under evaluation. For any particular group of people, a food system must deliver goods regularly and frequently so that people can eat as often as they need, multiple times a day. Once this constraint is met, we can then look at net performance over a variety of timescales. To allow the easy comparison of different cycles of production, annual yield is commonly used and is a valuable starting point. However, amortizing across years for yields and costs allows for the convenience of annual calculations but takes into account longer-term effects for comparison. Some such longer timescales include by decade, across a grower's career, across a grower's lifetime, across the lifespans of all currently living people, across the lifespan of any living organism in a system under consideration, across seven generations, across all impacts of our actions, and across perpetuity. The longer the period measured, the more the consequences of internal actions become manifest, such that it is a better proxy for sustainability, but also the greater potential variability of external conditions. It seems that the right period is to carry the standard of continual present viability as far forward as can be projected, in order to get to systems that are currently feasible, likely robust over further conditions, and acceptably meeting goals throughout.

Before leaving this topic, it is worth offering some methodological advice to avoid objective shifts. The idea is that instead of shifting objectives, what we really want to do is add them, so that we now have a Pareto space in which meeting some objectives at the cost of others is now a possibility. In this approach, any set of systems that are better in any observable way can be uncovered by scoring better in a particular weighting each of the objectives. We can temporarily discard any objective by giving it no weight. We would also like to move secondary objectives (i.e. "you can't meet this objective reliably without meeting these other objectives") out of designing the objective space and into technology assessment. This leaves us with further future work, which is designing information technologies, suitable to both manual and computerized uses, that allow this objective space to be preserved and assessed against appropriate assessment timescales on a weighted basis.

Recent Developments

As observed from the more recent permaculture materials cited as well as a variety of podcasts, websites, and personal conversations, the permaculture community is quite aware of the challenges that it faces and is taking a variety of positive actions to address them. It is building viable projects that will last, based both on broad surveys and demonstrations and also on focused longitudinal work.

First and foremost, in order to have permaculture projects last, both for their own sake and to get the longitudinal data necessary to truly learn best practices, we need projects that succeed. Inside the permaculture community, there has been the recognition that pragmatic, profitable, broadacre-scale approaches are necessary for working farmland to be allocated to permaculture applications. For this reason, Mark Shepard and others have been developing the restoration agriculture (Shepard, 2013) approach, predicated on developing a silvopastoral system mimicking oak savanna ecologies.

Shepard focuses on developing per-acre full-spectrum nutrition production superior to conventional techniques. This system also seems to have competitive commercial profitability when amortized over a decade through sharply reduced input costs, which also become a metric of performance by ecological measures. Significant establishment costs are cushioned by retaining the ability to raise annual crops through alley cropping, with perennial shrub and tree rows with sufficient distance between them as to allow mechanized annual cropping operations. This system provides a clear technical approach amenable to scientific studies currently underway (Wolz et al., 2015).

Permaculture's scholarship has also seen great improvements. One notable set of contributions is the work of Eric Toensmeier, who has contributed great catalogues of perennial vegetables (Toensmeier, 2007), staple perennial plants (Ferguson & Toensmeier, 2014), and plant species appropriate for forest gardening (Jacke & Toensmeier, 2005a), and along with Jonathan Bates cultivated a long-running and widely noted urban permaculture garden (Toensmeier & Bates, 2013). This scholarship has included gathering community knowledge about the site-specific appropriateness of perennial crops through the Apios Institute wiki (Apios Institute, 2015). This work attempts to catalogue the true breadth of perennial food resources, of which few people are aware.

In addition to the breadth of perennial food sources, the permaculture community could really benefit from a comparable level of species-specific analysis, as many of the plants discussed have not seen any real development of varieties for climate tolerance, disease resistance, nutritional improvement, yield, or other desirable characteristics. One group working in this area around nut trees has been the Badgersett Research Corporation, who have worked steadily to improve varieties of hazelnut (Rutter, Wiegrefe, & Rutter-Daywater, 2015) and chestnut in the Northeastern United States.

Overall, the permaculture community is pursuing the development of using viable methods with appropriately vetted knowledge. There are many other areas of recent improvement that are not covered here, such as a renewed attention to financial permaculture. It is appropriate to think of the role of systemic designers not as bringing new innovations to the community, but joining the work of improvement in a movement with an increasingly healthy self-critical and reflective side. With that in mind, let us now look to some areas for further development from the perspective of this work.

Further Work

The systemic challenges laid out above may each be addressed in a number of ways. The problem of stakeholder engagement is one area that clearly overlaps with contemporary work on design methods. The clearest extension of this work will be to take on the question of technology evaluation. We will want to evaluate solutions not only against sectors as they stand today but to fully embrace the futures-aware aspect of permaculture and engineer solutions resilient to what sectors may still emerge. We need to formulate experimental design comparisons thoughtfully so as not to unduly delay progress in a domain with a combinatorial explosion of possibilities. In particular, variable-by-variable control seems a dubious way forward, and instead we may want to more broadly compare the space of possibilities to immediately capture coarse effects. Altogether, the analytical side of permaculture has many parallels to contemporary engineering design, and it may just be a matter of extending and formalizing what is already there to establish a technology evaluation for its practitioners.

In each of these challenges, there may be some supporting information technology. In PDM, there is repeated reference to the power of information and the potential role of computing, but such developments seem little explored, with the exception of computer-supported communication. All of the information support systems that PDM describes could be laid out in relational terms and shared effectively using today's networking technology. One aspect not to be neglected in this process is the opportunity for new forms of visual communication as permaculture applies its analytical methods to new areas. The systemic development of information systems for permaculture is thus a major direction for development.

Combining the ideas of information systems and technology assessment would permit the development of systems that help assure that critical angles are sufficiently explored. One way to improve the economic and social viability of a project is to subject it to a comprehensive ontology that makes sure it has worked through all of the interconnections that justify its viability and value. There are now such ontologies for strongly sustainable business models that have commitments to representing and designing for ecological, social, and economic outcomes (Jones & Upward, 2014; Upward & Jones, 2016). Surely these can be applied to aid permaculture projects from a systemic perspective.

Conclusion

Overall, this paper is aimed to introduce permaculture as a set of design practices that both offer much to and greatly benefit from interaction with the systemic design community. Permaculture offers systemic design a well-established path into the agroecological design necessary to complement developments in agroecological engineering. We have seen how permaculture emerged from a synthesis of ecology, agriculture, design, and planning and has rapidly gained widespread popular interest. We saw the many ways in which permaculture practitioners—to both benefit and detriment—have similar training, methods, professional issues, and sense of appropriateness as designers. Permaculture has offered many design contributions, including a clear ethical mandate, design methods including an analytical discovery process, and specific agroecological and social system design approaches. At the same time, permaculture faces a variety of systemic challenges, including clarifying objectives, assessing approaches, engaging stakeholders, building institutions, creating logistical networks, developing viable businesses, and developing long-term knowledge. It is clear there are approaches to address each challenge compatible with permaculture's overall logic, as we saw with building systems of objectives that process, produce, or maintain with given costs as amortized over periods of time. Those in the permaculture community are making great strides in a number of these areas, and it is our future work to join them in systemic improvement.

The work of agroecological systemic design is more important than ever. With herbicide-resistant plants progressively emerging, we may find that within 15 years conventional agricultural approaches will not be feasible at the scale to which it has been developed in the past. Currently, many farmers are locked in and must continue working at this scale to amortize the cost of the equipment necessary to work at this scale. At the same time, the average age of farmers in the United States is now in the 50. At the time in which change must happen, a transition to a new generation of farmers without the current debt structure may allow it to happen. The question is what a new generation of farmers will do with this new possibility.

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