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Juval Portugali
Egbert Stolk *Editors*

Complexity, Cognition, Urban Planning and Design

Post-Proceedings of the 2nd Delft International Conference

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His research integrates complexity and self-organization theories, environmental-spatial cognition, urban dynamics, and planning in modern and ancient periods. His publications include *Implicate Relations: Society and space in the Israeli-Palestinian conflict*, Kluwer 1993. *The Construction of Cognitive Maps*, Kluwer, 1996 (Ed.). *Self-Organization and the city*, Springer, 2000. *Complex Artificial Environments*. Springer Complexity Series, 2005 (Ed.). *Complexity, Cognition and the City*, Springer, Complexity Series 2011. *Complexity Theories of Cities Have Come of Age, Springer*, Complexity Series 2012 (Ed.). *Information adaptation: The interplay between Shannon information and semantic information in cognition*. SpringerBriefs. Springer, Heidelberg, Berlin. (2015), by H. Haken and J. Portugali.

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Egbert Stolk is a researcher at the Department of Urbanism at the Faculty of Architecture and the Built Environment, Delft University of Technology. He is research leader of the Design of the Urban Fabric Research Group, and editor of the Journal of Design Research. He has worked Dutch urban design practice for several years.

In his Ph.D. thesis he integrated the SIRN approach, as developed by Haken and Portugali, with notions from psychology, design thinking, and urban design. His publications include: *Model Town: using urban simulation in new town planning*, SUN, 2009 (Ed.); *Complexity Theories of Cities Have Come of Age*, Springer, Complexity Series 2012 (Ed.).

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He has worked on computer models of cities and their visualization since the 1970s and has published several books, such as Cities and Complexity (MIT Press 2005) which won the Alonso Prize of the Regional Science Association in 2011, and most recently The New Science of Cities (MIT Press 2013). His blogs www.complexcity.info cover the science underpinning the technology of cities and his posts and lectures on big data and smart cities are at www.spatialcomplexity.info. He is the editor of the journal Environment and Planning B. His research group is working on simulating long-term structural change and dynamics in cities as well as their visualization, as well as urban analytics for smart cities. He has various awards for his work; most recently he was the 2013 recipient of the Lauréat Prix International de Géographie Vautrin Lud, and in 2015, he received the Founders Gold Medal of the Royal Geographical Society.

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Efrat Blumenfeld-Lieberthal is a Senior Lecturer at the David Azrieli School of Architecture at the Tel Aviv University. She received her B.Arch., MA, and Ph.D. at the Faculty of Architecture and Town Planning, at the Technion—Israel Institute of Technology. She worked as a postdoctorate researcher at the Center for Advanced Spatial Analysis (CASA), University College London and as a Porter Fellow at the Environmental Simulation Laboratory (ESLab), Tel Aviv University.

Her research interests are applying theories of complexity to urban environments; urban morphology; size distribution of entities in complex systems; smart cities; and complex networks in urban systems. Her work was published in leading professional journals in the fields of urban studies and physics. Following are three of her recent publications:

- E. Blumenfeld-Lieberthal, The Topology of Transportation Networks: A Comparison Between Different Economies, *Networks and Spatial Economics*, Vol 9, 2009, pp 427–458.
- E. Blumenfeld-Lieberthal and J. Portugali. MetroNet: A Metropolitan Simulation Model Based on Commuting, *Lecture Notes in Computer Sciences*, 2012, Volume 7166/2012, pp. 96–103, DOI: 10.1007/978-3-642-28583-7_10.
- N. Serok, and E. Blumenfeld-Lieberthal: A Simulation Model for Intra-Urban Movements, PloS one 10.7 (2015): e0132576.

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Gert de Roo (1963) is Professor of Spatial Planning and Head of the Department of Spatial Planning and Environment, the Faculty of Spatial Sciences, at the University of Groningen, The Netherlands. De Roo has great interest in a number of topics, all related to choice making regarding interventions in public space. His research focuses on

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- linking the complexity sciences with spatial planning,
- the rationalities of planning and decision-making,
- the development of decision-making models supporting choices concerning interventions within the urban environment,
- relating complexity thinking and planning theory, and
- managing transitions of space.

His books on ‘complexity and planning’ are “A Planner’s Encounter with Complexity” (2010, Ashgate Publishers), and “Planning & Complexity: Systems, Assemblages and Simulations” (2012, Ashgate Publishers). Other recent books are on ‘Fuzzy Planning’ (Ashgate 2007) and ‘Regions in Transition’ (2011, 010-publishers). De Roo has been President of the Association of European Schools of Planning (AESOP) representing 150 Schools of Planning throughout Europe. He has been as well as co-chair of the International Urban Planning and Environment Association (UPE). He has been editor of the Ashgate Publishing Series on Planning Theory. And De Roo is currently Editor in Chief of AESOP’s digital platform InPlanning to sharing knowledge on spatial planning, focusing on e-books, e-journals, videos, lecture programs, etc. De Roo is also Visiting Professor at Newcastle University. For more information, see De Roo’s homepage: http://www.rug.nl/staff/g.de.roo/index.

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Andy Dong is a design researcher and practitioner and is currently appointed Professor as the Warren Centre Chair for Engineering Innovation at the University of Sydney. This Chair will lead a program of education and research in engineering innovation in Australia.

With a background in mechanical engineering and artificial intelligence, Prof. Dong is a distinguished researcher in the areas of computational design and design cognition. His research tests the theory that the structure of knowledge underlying a technological innovation has a strong relation to its long-term progress potential, the productivity of the design process leading to its commercialization, and its robustness and resilience.

Professor Dong regards design as one of the most complex problems for the art, science, and engineering communities. Building on his initial training in mechanical engineering at the University of California, Berkeley, his research interests explore design competence and new ways of fostering innovation and innovative thinking through design processes.

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John Habraken is a Dutch architect, educator, and theorist. His major contributions are in the field of mass housing and the integration of users and residents into the design process.

From 1965 to 1975, he was Director of SAR (Foundation for Architects Research) in the Netherlands, researching and developing methods for the design and construction of adaptable housing. Author of *Supports, an Alternative to Mass Housing* (1962), in which he proposed the separation of 'support' or base building from 'infill' or interior in residential construction as a means of giving inhabitants a meaningful participative role in the design process. In 1967 Habraken was appointed Professor at Eindhoven Technical University, and charged with the responsibility to set up its new Department of Architecture and serve as its first chairperson. From 1975 to 1981 Habraken served as Head of the Department of Architecture at the Massachusetts Institute of Technology (MIT), Cambridge, MA. He taught at MIT until his retirement as Professor Emeritus in 1989.

Habraken remains occupied with methods and theory of architectural and urban design. He has lectured on these topics worldwide and is the author of a vast number of books, research reports, and many articles.

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As the original pioneer of the methods for the analysis of spatial patterns known as 'space syntax,' he is the author of *The Social Logic of Space* (Cambridge University Press, 1984, 1990) which presents a general theory of how people relate to space in built environments, *Space is the Machine* (CUP 1996), which reports a substantial body of research built on that theory, and a large number of articles concerned with different aspects of space and how it works. He has also written extensively on other aspects of the theory of architecture.

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Kelso has worked on coordination dynamics, the science of coordination, and on fundamental mechanisms underlying voluntary movements and their relation to the large-scale coordination dynamics of the human brain. His experimental research in the late 1970s and early 1980s led to the HKB model (Haken–Kelso–Bunz), a mathematical formulation that quantitatively describes and predicts how elementary forms of coordinated behavior arise and change adaptively as a result of nonlinear interactions among components.

Kelso has held visiting professorships in France, Germany, Russia, and (currently) Ireland. He has also lectured extensively in the USA and abroad. He has received many honors and awards for his scientific research. In 2007, he was named Pierre de Fermat Laureate.

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Stephen Marshall is Senior Lecturer in Urban Morphology and Planning at the Bartlett School of Planning, University College London. Dr. Marshall has over 20 years' experience in the built environment fields, initially in consultancy and subsequently in academia.

His principal research interests are in urban morphology and street layout, and their relationships with urban formative processes, including urban design, coding and planning. He has written or edited several books, including *Streets and Patterns* (2005), *Land Use and Transport* (with David Banister), *Cities, Design and Evolution* (2009) and *Urban Coding and Planning* (2011). He was Chair of the Editorial Board of *Urban Design and Planning* (*Proceedings of the Institution of Civil Engineers* journal series) from its launch to 2012; and is now co-editor of *Built Environment* journal.

University College London, UK

Han Meyer has been a Full Professor of Urban Design—Theory and Methods at the faculty since 2001. He concentrates on the fundamentals of urban design, the development of design methods and critical reflection of contemporary urban design practice. He is leading the research program 'Delta Urbanism,' which focuses on the design and planning of safe and livable urban areas in delta regions all over the world. The 'delta condition' can be considered an extreme example of the necessity for urban designers to pay attention to the natural and environmental context of existing and new urban areas.

Meyer was advisor of the Dutch Delta Program, the Greater New Orleans Urban Water Plan, The Lisbon Urban Flooding Research Program and the Kaoshiung Water Management program.

He is co-author of the book *New Perspectives on Urbanizing Deltas* (MUST Publishers, 2015) and *De Staat van de Delta* (*The State of the Delta*), 2016.

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Roni Sela is a psychologist with research interests in human factors in complex systems. She has a Ph.D. from the Porter School of Environmental Studies in Tel Aviv University, and also has a BA in Psychology and Geography and MA in Industrial and Organizational Psychology, both from the University of Haifa. Her Ph.D. study focuses on cognitive aspects of planning and their implications for urban planning.

Tel Aviv University, Israel

Ekim Tan Born in Istanbul, Ekim Tan graduated as an architect from the Middle East Technical University (METU) with the Archiprix Award in 1999, and received her second degree in urbanism of the Technical University Delft with distinction in 2005. More recently she founded the Amsterdam and Istanbul based city design and research network 'Play the City.'

This network focuses on strategic urban development in emerging countries, therefore consists of young and ambitious professionals from Cairo to Istanbul to Amsterdam. She is an experienced researcher and designer in international urban design projects. Her hybrid worldview has been shaped by diverse cultural conditions of the east and west, Islam and Christianity, poverty and prosperity.

Besides running this practice, Tan is active in the academia through research and teaching. In 2014 she finalized her Ph.D. thesis at the Department of Urbanism, Faculty of Architecture and the Built Environment, Delft University of Technology, and at the International New Towns Institute, INTI, in Almere.

The City Gaming Method developed by Tan has been applied worldwide, in global cities including Istanbul, Amsterdam, Shenzhen, Tirana, Cape Town, and Brussels.

Play the City

Paul Thagard is a Canadian philosopher who specializes in cognitive science and the philosophy of science. Thagard is Professor of Philosophy at the University of Waterloo, where he runs the Cognitive Science Program. Thagard has published 10 books and more than 200 articles on topics such as conceptual revolutions, analogy, and emotional thinking. His most recent books are *The Brain and the Meaning of Lif*e (Princeton University Press 2010) and *The Cognitive Science of Science* (MIT Press 2012). Thagard is currently working on a three-volume *Treatise on Mind and Society* that shows the relevance of new theories of cognition and emotion for the social science, professions, and humanities.

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J. Scott Turner is Professor at the State University of New York, Syracuse, College of Environmental Sciences and Forestry, at the Department of Environmental and Forest Biology. He has contributed to the theory of collective intelligence through his fieldwork on the South African species of termite Macrotermes michaelseni, suggesting the architectural complexity and sophistication of their mounds as an instance of his theory of the extended organism. His theory was reviewed in a range of journals, including Perspectives in Biology and Medicine, the New York Times Book Review, EMBO Reports, and American Scientist.

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Barbara Tversky is Professor of Psychology and Education at Columbia Teachers College and Professor of Psychology Emerita at Stanford University and taught previously at the University of Michigan and Hebrew University of Jerusalem. She holds BA, MA and Ph.D. degrees in Cognitive Psychology from the University of Michigan. She is a fellow of the American Academy of Arts and Sciences, the Cognitive Science Society, the Association for Psychological Science, and the Society for Experimental Psychology.

Her research has spanned memory, categorization, spatial thinking, language, and memory, event cognition, diagrammatic reasoning, visual communication, gesture, design, and creativity. She has enjoyed collaborations with linguists, philosophers, computer scientists, designers, artists, geographers, biologists, chemists, and more.

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Introduction

Juval Portugali and Egbert Stolk

This book follows the 2nd Delft International Conference on *Complexity, Cognition Urban Planning and Design* that took place at the Department of Urbanism, Delft University of Technology, during October 10–12, 2013. While the aim of the 1st Delft international conference was “to look back at what has been achieved […] and then also to look forward to potentials and challenges that have yet to be materialized and achieved.” (Portugali 2012: 1), the aim of this second meeting was to respond to the idea of cities as complex systems, or more specifically to the dilemma posed by the fact that cities are at once simple and complex systems, as implied by Complexity Theories of Cities (CTC)—a domain of research that, in the last four decades, has become a dominant paradigm in the study of city planning and design (Batty 2013; Portugali 2011). Similarly to complex systems in both the animate and the inanimate domains, cities exhibit various properties inherent to natural complex systems: they are open, complex, emerge bottom-up, tend to have fractal structure, and are often chaotic. As a consequence, many of the mathematical formalisms and models developed to study material and organic complex systems also apply to cities. At the same time, however, cities are large-scale collective artifacts, and artifacts are, by definition, simple systems. So what is it that makes the simple system and artifact ‘city’ a complex system?

The answer: The activities and interactions of human urban agents transform the artifact ‘city’ into a complex system ‘city’ (Portugali 2011). It is in this respect that cities differ from natural complex systems; they are *hybrid*, artificial–natural complex systems (ibid) composed of human agents as individuals and collectivities, both of which are by their nature complex systems, and artifacts of various forms and scale, built by the human agents, which are essentially simple systems. From this follows a need, addressed by CTC, to add the insight of cognitive science to the study of urban agents and their behavior and action in cities. This insight allows a whole set of new questions to emerge: What are artifacts, and in what ways do they differ from natural entities? How are they constructed? How is the city as a hybrid natural–artificial entity coordinated? What is the role of planning and design in the dynamics and coordination of cities? Who are urban planners and designers, how do they plan and design, and by what means? What is the role of cognitive faculties such as memory, emotions and creativity in the processes of planning and design? What role do "latent" (that is, non-professional) and professional designers and planners play?

The answers to these questions cannot come from a single discipline; rather they must arise out of a discourse between experts from several disciplines, ranging from CTC to cognition, urban planning and design. The fact is, however, that due to current disciplinary boundaries, experts from these domains do not often interact with each other. This was exactly the challenge taken on by the 2nd Delft International Conference on *Complexity, Cognition Urban Planning and Design*. Its participants, complexity theorists, cognitive scientists, philosophers, urban designers, zoologists, and more—see the list of contributors to this volume—engaged in intensive discourse on the questions above. This book is a second round of transdisciplinary collaboration: Following the discussions and discourse that took place in the conference, each author has rewritten her or his paper in line with this discourse. The discussion in the book develops in four parts that are described next.

Part I—Complexity, Cognition and Cities

Six general statements, in six chapters, about complexity, cognition, and cities form Part I: It opens with a chapter by Juval Portugali that tackles the question "what makes cities complex?" by suggesting, as noted above, that cities are hybrid, artificial–natural entities and that it is due to the nature of their parts—the urban agents with their planning and design cognitive capabilities—that they are complex systems. The paper elaborates on the property of *chronesthesia* (Tulving 1983) that typifies urban agents, namely their ability to mentally travel in time back to the past and forward to the future; one manifestation of this property is humans' tendency to plan and design. Finally, it suggests the notion of *information adaptation* (Haken and Portugali 2015) as a theoretical framework for studying planning and design in general and of cities in particular.

Complexity theories of cities have added a new understanding of cities and a whole set of methodologies to the study of cities, and in particular to urban simulation models. In the second chapter, Michael Batty adds two aspects to the domain of urban simulation modeling that were, until now missing from the discussion: design and planning. Batty's contribution introduces a class of decision models designed to resolve conflicts and reach a consensus between urban stakeholders in situations where planners and designers (here termed 'agents') come forward with varying opinions regarding a given urban area. Drawing upon early studies on social power by French (1956) and Harary (1959), as well as Coleman's more recent model of collective action (1994), Batty's model evolves as a Markov averaging which produces a solution (the best plan or design) as a weighted average of the initial opinions. Having introduced the model, Batty then illustrates its potential by applying it to a somewhat simplified real-world case study of current planning and design conflicts in a five-hectare area in the City of London.

On the face of it, the duality of cities as hybrid complex systems implies a tension between the contraries 'natural' and 'artificial.' Scott Kelso et al. contribution to the debate, in Chap. 3, suggests a different perspective on this duality that starts out from Kelso and Engstrøm's (2006) "philosophy of complementary pairs." Based on empirical evidence regarding the coordinated dynamics of brain activities, Kelso and Engstrøm claim that, due to the ubiquitous human tendency to dichotomize, many things, events, and processes appear to be contraries; yet in reality they are, in fact, mutually related and inextricably connected. They assign the tilde (~) as an indicator of a complementary pair. Cities, Kelso et al. show, are typified by cases of seeming contraries that are in essence complementary pairs. This applies to complementary pairs that affect the overall dynamics of cities, such as natural ~ artificial, as well as to the design ~ self-organization pair to which the paper devotes special attention.

Having established in the first three chapters that cities are indeed complex artifacts made by humans, John Habraken takes the question one step further in Chap. 4, emphasizing that when we look at cities closely we can identify two kinds of complexity: *technical complexity* that characterizes the current stage of urban planning and design and *non-technical complexity* that prevailed in past generations and was typified by continuous small-scale changes over time. We live in a period of transition, Habraken claims, that requires a shift from technical to non-technical complexity: from planning and design that "make environmental things" to planning and design that "as gardeners [...] cultivate a living field."

The final two chapters of Part I, by Bill Hillier and Andy Dong, explore the role of creativity in the complexity of cities; Bill Hillier does so from the perspective of his space syntax approach to the study, planning and design of cities (Hillier 1999), while Dong applies the perspective of cognition and design thinking to the question. There is clear evidence that "cities create creativity," writes Hillier, but what is not yet clear is how; "space syntax," he adds, "doesn't seem to help with this question." According to Hillier, *creativity* is the fourth urban sustainability, the first three being *energy*, *society*, and *economics*. However, unlike the first three, which are driven by urban space and thus by space syntax, creativity seems to be driven by social networks which, while they have spatial forms, are essentially "driven by non-spatial factors which do not seem to map significantly onto the micro-to-macro-scale analysis we associate with space syntax." The aim of Hillier's paper is to expose the forces that create creativity in cities. He does this by looking at the structure of social networks that are formed within cities, ranging from networks of within-group, daily and sort-distance contacts, to networks of between-group, random and long-distance contacts. In between the two, Hillier identifies networks at "the *right conceptual distance*." These social networks that are conceptually and spatially "neither too close nor too far" are the creators of urban creativity.

Dong's paper comprises two parts. The first is an extensive scrutiny of design as a uniquely human cognitive capability. In particular, Dong emphasizes three cognitive skills (*recursion*, *representation,* and *curiosity*) which according to him are fundamental to design thinking and by implication to creative cities. Based on this analysis, the second part of the paper suggests that human creativity is strongly associated with environmental properties and addresses the question: What structures and properties of cities enhance creative design? Such cities, responds Dong, should facilitate “opportunities for opportunistic encounters to encourage out-of-domain analogical transfer of ideas.” They should also cultivate “complexity in form to induce the generation of frames of increasing number and novelty about the meaning of city forms,” and embody “cumulative cultural knowledge to inform and enhance future design iterations.”

Part II—On Termites, Rats and Cities

The view that cities are hybrid artificial–natural systems bring with it the need to define the distinction and relationship between the natural and the artificial, which Part 1 look at, as well as to address the extent to which the study of animal behavior can teach us about human behavior. Part II looks at two natural phenomena that have a high level of resemblance to the artificial phenomena that typify cities: termites’ ‘architecture’ and rats’ spatial behavior regarding the entity ‘home.’

The large mounds built by the termites of the genus *Macrotermes* are some of the most remarkable animal-built structures on the planet. Living in colonies of about “2 million sterile individuals, all of them the offspring of a single fertile female, the Queen,” explains physiologist Scott Turner in Chap. 7, these termites collectively construct a massive mound built from several tons of soil, usually two to three meters in height: a kind of a termite city. According to Turner’s (2002) theory (and book) *The Extended Organism,* the mound is an extended physiological entity—a gas exchange infrastructure that functions in a way similar to the lungs, heart and circulation of a single animal. What is specifically remarkable is that the mound/city is being built, maintained, and repaired by a huge number of individuals that work in a highly coordinated way, yet with no central planner, designer, or leader; they are organized, instead, by a genuine process of self-organization and of *swarm cognition*. What lesson, if at all, can urban planners and designers take from nature in this case? Turner’s careful answer is that, similarly to the role of genes, the role of planning and design is not to impose order but to facilitate “the ability of the many cognitive agents—citizens—that make up our cities to judge their environments for themselves and their many individual judgments of how they can best construct their environments.”

For these 2 million termites, the mound provides a single *home*; can a human city be perceived as ‘home’ for all its inhabitants? In Chap. 8, architect Efrat Blumenfeld-Lieberthal and zoologist David Eilam suggest that in certain circumstances, a city can. In their paper they explore comparatively the many facets of the notion ‘home,’ as it can be defined by studies on animal and human behavior. For both humans and animals home is usually a physical construct, whether a building or a den, that provides shelter and storage. But, as shown by the example of termite mounds, home can refer to different levels of scale: an apartment in a building, a town (hometown) or a country (homeland). They show that 'home' is also associated with specific emotions and home-behavior, providing a base for movement into the "external" world where behavior is different. This routinized movement from the "internal" home to the "external" environment is basic to animals, humans included. The need for a home, Blumenfeld-Lieberthal and Eilam go on to show, also dominates the behavior of "homeless" animals and humans, who in the absence of a permanent home create *ad hoc* homes.

Both papers emphasize similarities; but what about the differences? Are there differences? Following Chap. 1, our answer is that there is a fundamental difference: Animals are subject to the slow process of Darwinian evolution that determines the way termites build their mound and many other animals their homes; human are "subject to two evolutionary processes: very slow natural evolution and very fast cultural evolution." Unlike the termites' mound-city, the structure of humans' home-city has evolved dramatically, so much so that as illustrated by Portugali (2000, 11–16), there is very little similarity between a city in antiquity and a modern city beyond the term "city."

Part III—Complexity, Cognition and Planning

Complexity theory entered the study of cities through two gateways: One opened when physicist Peter Allen applied Prigogine's dissipative structures to urban dynamics; another opened more recently when students of urban planning applied the notion complexity to the problematics of planning in twenty-first century. Chapters 1 and 2 are representative of the first, while Chap. 9, by Gert de Roo's that opens Part III, is a representative of this second route. He portrays the recent history of planning as a pendulum moving between two extreme positions or *cognitive frames*, as he call them: *Realism* at one end and *relativism* on the other. The first gave rise to the technical 'rational-comprehensive planning' approach that dominated the field in the 1950s and 1960s, while the second to recent Habermasian communicative or 'collaborative planning.' In between, argues de Roo, there is "an endless variety of combinations of these two realities" of which he elaborates on two: 'relationalism' and 'idealism,' where the latter is associated with what de Roo terms 'the world of becoming' or *dynamic complexity*. The aim of the chapter is to explore a planning reality in the context of "four rather than two cognitive frames."

Urban planning is traditionally based on planners' capacity to predict or envision the future; and yet, one of the implications of CTC is that cities are ontologically unpredictable—not as a result of lack of data, but inherently so. This inherent unpredictability has led to a search for a planning approach based not on predictions but rather on planning rules (Portugali 2011, Chap. 16). Roni Sela, in Chap. 10, examines 'prediction free' planning through the lens of *cognitive planning*, a research domain developed in the context of psychology and cognitive science. By so doing she creates a link between two domains that has not been fully explored before: 'cognitive planning' and professional planning as studied and practiced in connection with cities. Sela presents empirical evidence of a "basic human tendency to continuously predict the future," from which follows that, even in prediction-free urban planning systems, some form of future urban vision is cognitively required.

In Chap. 11, Paul Thagard approaches planning and design from the perspective of cognitive philosophy. He starts by noting that the various cognitive processes associated with planning and design, such as cognitive planning, learning, and decision-making, involve value judgment, a view widely agreed on in planning and design discourse. To this Thagard adds a new aspect not yet studied in the domains of cities and their planning: The various planning processes "have a large emotional component." Thagard approaches his basic question—"How does emotional cognition contribute to urban planning?"—by introducing Cognitive Affective Maps (CAM), a methodology developed by him as means to portray alternative planning situations in terms of values and emotional states. He then employs the notion of *emotional coherence* as means to identify cognitively and socially acceptable planning solutions, illustrated by reference to planning case studies as well as to cities and creativity. He ends by positioning his work in relation to the link between cognition and complexity.

Part IV—Complexity, Cognition and Design

The above three chapters about complexity, cognition and planning that make up Part III are complemented in Part IV by four chapters on the relations between complexity, cognition, and design, with a special emphasis on urban design.

The emphasis on urban design is significant as most previous studies on design and design thinking were developed by reference to small-scale design objects, overlooking the implications of designing at different levels of scale. Chapter 12, by Stolk and Portugali, focuses on the role of levels of scale in design, approaching this issue from a conjunctive perspective of Synergetic Inter-Representation Networks (SIRN) and Construal Level Theory (CLT). SIRN refers to complex systems that evolve as an ongoing sequential interaction between internal and external representations (Portugali 2011, Chap. 7; Stolk and Portugali 2012; Portugali and Stolk 2014), while CLT (Liberman and Trope 2008) explores the relation between psychological distance and the extent to which people's thinking is abstract or concrete. The paper shows that distant objects are thought of as being more abstract, while close objects are perceived as being more concrete. From the conjunction of SIRN and CLT Stolk and Portugali demonstrate that "design objects at different levels of scales imply […] different cognitively embodied relations between the designer and the object and as a consequence activate different cognitive properties and capabilities of the designer." These differences in scale are related to the external representations used in the design process, in various design media, as well as to the distinction between closed-simple design artifacts and open-complex design artifacts (see Chap. 1). Urban designers design across scales, moving back and forth along different scale-distances, while representing the designed object (neighborhood, city, etc.) using various design media with different levels of abstraction. Using an example from Dutch urban design practice, the paper concludes by showing how the open-complex nature of urban design processes is facilitated by abstract representations on different scales.

Chapter 13 by Barbara Tversky elaborates on what to many is the most basic element of design—*the line*. Commencing from the view that “architecture is information,” she shows that architects design and thus inform by means of various kind of lines: First, at the design stage, by means of messy lines—“lines of thoughts” of sketches—that because of their messiness and uncertain character have the potential to invoke new ideas and solutions and thus play a significant role in the creative process of design. The sketches that represent lines of thoughts and imagination are then transformed into the lines of maps and plans that eventually give rise to the concrete lines of buildings, streets, parks, and the other elements that form cities, and once again inform: Horizontal and vertical orderly lines inform the function of architectural elements such as entrances, windows, roads, pavements, and bridges, while curved lines inform roads’ roundabouts and imagined “dotted” lines inform colonnades.

The next two chapters of Part IV look at the very process and practice of urban design, dealing with open-complex design processes as defined by Stolk and Portugali in Chap. 12. In Chap. 14 Stephen Marshall “returns” to Christopher Alexander’s approach to urban design, in particular to Alexander’s (1965) seminal paper “A city is not a tree,” one of the forerunners of CTC. Written in the first half of the 1960s, as the first complexity theories were being formulated, Alexander describes the properties of cities in language that today would be used to describe complex systems. What is specifically interesting in Alexander’s paper and relevant to the present discussion is that his main concern was urban design—a process that has only recently been considered by CTC. In “A city is not a tree,” Alexander (1965) discusses the cognitive constraint responsible for the failure of contemporary urban design to create the high quality built environments of the past; in particular the difficulty planners and designers face trying “to conceive the kind of complexity found in traditional urban structures in a single mental act.”

Alexander et al. book *A Pattern Language* (1977) was, according to Marshall, an attempt to overcome this cognitive constraint. In his paper, Marshall first discusses the various aspects of the pattern language and then evaluates the extent to which the pattern language as a design tool can give rise to the desired complex urban structures. His evaluation is based on a set of experiments with students’ use of the pattern language in their urban design projects. “Overall,” reports Marshall, “the students were able to produce designs using the patterns, demonstrating to some extent the viability of patterns as a way of generating urban development.” Marshall ends by looking at the limitations of the method, such as that “when it comes to design, they are not the most intuitive building blocks,” or that “the users of the book (in this case, students) sometimes find pattern language difficult to apply.” Marshall concludes his chapter by indicating a need for collective, incremental codes for a controlled design process.

The chapter that follows, by Ekim Tan, suggests such a design process. In her paper Tan demonstrates how the *city game*, originally developed by Portugali (1996) as a didactic device and an illustration of self-organization in the city, can become a platform for a practical, collective, bottom-up, self-organized, codes-controlled urban design process (Tan and Portugali 2012). She illustrates this by reference to *Play the City*, an organization developed by her through the doctoral research, and through which she has experimented on various collaborative urban design gaming projects. Tan's aim in her contribution is ambitious: To develop *Generative City Gaming*: "a generative medium for making and maintaining (real) cities, [...] built to respond to real-world complexities." The first part of her paper is a historical survey of the literature on gaming in general and planning games in particular. She then introduces six city games played mostly with real stakeholders between 2008 and 2013 as an experimental means to develop her Generative City Gaming method. Each of these city games addressed a real site in an urban setting, and each added another dimension to the generative city gaming approach, helping to transform it "from a hypothetical simulation test about how self-organization principles could help order a new town expansion in 2008, to a complete game outcome implementation in 2012." Tan concludes her paper by discussing the potential and limitations of the method and by posing open questions; Tan wonders if the city game as a design tool can be applied to a metropolitan scale, and consequently whether there is a scale limit to the design process. As noted in connection with Stolk and Portugali's chapter, design thinking was developed mainly by reference to very small objects with the implication that urban design is an exception. But, Tan notes, even within urban design there is a scale limitation; current urban design usually deals with parts of cities (neighborhoods) and rarely with whole cities. The paper leaves us with the challenge: Can there be a metropolitan design?

Part IV closes with Han Meyer and Steffen Nijhuis's Chap. 16, which takes this question even further by examining the possibility of design at a regional scale. Focusing on the Dutch urbanized delta landscape, they explore the extent to which "design [can] play a role in the future development of urban regions, taking into account that these regions are extremely complex, with uncertain futures defined by many different processes with different rhythms." Referring to the Dutch delta with the Rotterdam metropolitan area as a test case, they start by presenting the complex relationship between the natural landscape and human interventions in general terms. They then provide an historical account of the changing views among planners and designers regarding these relations: from the twentieth-century modernist approach that attempted to "control the urbanization process in the delta landscape" by subjecting the natural landscape completely to the needs of human society, to later approaches advocating integrating design with nature such as the 'layer-approach' that became increasingly influential since the 1970s and gave rise to the 'framework-model' (in Dutch: *casco-concept*), through to present widespread recognition of the need for a 'Robust Adaptive Framework' that recognizes the complexity and uncertainties that typify the Dutch delta. Meyer and Nijhuis conclude by stating that "design research (the analysis of previous designs and patterns) and research by design (testing different possibilities for an area) both play an important role in this approach."

In closing this introduction, we would like to emphasize that the preparation and publication of this book and the conference upon which it is based are the fruits of teamwork that included many people: The authors who presented stimulating papers during the conference and later transformed them into full-scale papers; Yulia Kryazheva who played an important role in the organization of the conference; the staff of the Department of Urbanism at TU Delft orchestrated by Linda van Keeken; Diana Ibáñez López who language edited the 16 papers of this book and made them legible to a wider audience. We also would like to thank Frits Palmboom for his inspiring talk at the end of the conference, bringing together various topic addressed in the conference. His passionate contribution highlights two important topics to be addressed in future conferences: the role of emotion and imagination in urban planning and design. Finally, we should mention KNAW—The Royal Netherlands Academy of Arts and Sciences, and The Delft Infrastructures & Mobility Initiative (DIMI), for their financial support.

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Part I
Complexity, Cognition and Cities

Chapter 1
What Makes Cities Complex?

Juval Portugali

Abstract The rationale of this book follows dilemma (see introduction, this volume): The last four decades have witnessed the emergence of CTC (complexity theories of cities)—a domain of research that applies complexity theories to the study of cities. Studies in this domain have demonstrated that, similarly to material and organic complex systems, cities exhibit the properties of natural complex systems and, that many of the mathematical models developed to study natural complex systems also apply to cities. But there is a dilemma here as cities are large-scale artifacts and artifacts are essentially simple systems. So what makes the city a complex system? To answer this question I first draw attention to the ways in which cities differ from natural complex systems and suggest that, as a result, we have to include the cognitive capabilities of urban agents in theorizing and simulating the dynamics of cities. In particular, I draw attention to the fact that urban agents are typified by *chronesthesia,* that is, the ability to mentally travel in time, back to the past and forward to the future. From the recognition of this cognitive capability follows, firstly, a novel view on the dynamics of cities and the role of urban planners and designers in their dynamics. Secondly, a potential for a new field of study in which planning and design are not treated as external interventions in an otherwise spontaneous and complex urban process, but rather as integral elements in its dynamics.

1.1 The City as a Complex Artifact

In 1943, Nobel laureate Erwin Schrödinger gave a lecture at Trinity College Dublin entitled "*What is Life?*"; a year later Schrödinger published it as a book in which he approaches the question by reference to entropy: matter is subject to the second law of thermodynamics, that is, to the process of entropy, while life entails a dilemma

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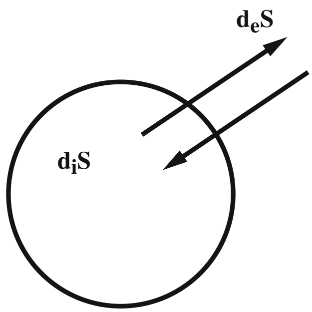


Fig. 1.1 Prigogine's Fig. 2.1 has the caption: "The exchange of entropy between the outside and the inside"

(Schrödinger 1944, Chap. 6): "How would we express the marvelous faculty of a living organism, by which it delays the decay into thermodynamical equilibrium (death)?" His answer is that by means of the process of metabolism a living organism "feeds upon negative entropy, attracting […] a stream of negative entropy upon itself, to compensate the entropy increase it produces by living and thus to maintain itself on a stationary and fairly low entropy level." This notion of negative entropy was later termed *negentropy* (Brillouin 1953).

Schrödinger's view of life and his suggestion that "organization is maintained by extracting 'order' from the environment" anticipated the notion of *order out of chaos* that has become *the* motto of complexity theory. Indeed, three decades later Ilia Prigogine demonstrated, in his Nobel lecture, that in certain circumstances matter also behaves as if it has life (1977). He showed, with the aid of Fig. 1.1, that:

> The classical formulation [of entropy] due to Clausius refers to isolated systems exchanging neither energy nor matter with the outside world. […] It is easy to extend this formulation to systems which exchange energy and matter with the outside world […]. We have then to distinguish in the entropy change dS two terms: the first, deS is the transfer of entropy across the boundaries of the system, and the second diS, is the entropy produced within the system.

Prigogine termed his theory of complexity *dissipative structures*. In more or less the same period Hermann Haken (1969, 1987) developed a theory of complexity that he called *synergetics*, while Lorenz (1963) developed the theory of *chaos*; a few year later Mandelbrot (1983) developed his *fractal geometry*, Bak (1996) his *self-organized criticality*, and more recently *the new science of networks* was introduced by theorists such as Barabasi (2002) and Watts (2004). While all of the above refer to open and complex systems in far from equilibrium conditions, each of these theories emphasizes specific aspects of complexity.

Complexity theories' connection to towns and cities was there from the start. Thus in his Nobel lecture Prigogine said (1977):

> Are most types of 'organizations' around us of this nature [that is, characterized by thermodynamic equilibrium]? […] the answer is negative. Obviously in a town, in a living system, we have a quite different type of functional order. To obtain a thermodynamic theory for this type of structure we have to show that non-equilibrium may be a source of order.

This usage of the city as a metaphor for complexity appears time and again in Prigogine's further writings. However, it was Peter Allen, a former student of Prigogine, who first developed a complexity theory of cities (Allen 1997) and by so doing created the domain of CTC—*complexity theories of cities*. Developed by a small but active community of researchers, studies in CTC have demonstrated that cities exhibit all the properties of natural complex systems: they are open, complex and self-organized, and often fractal and chaotic. They have further shown that many of the mathematical formalisms and models developed to study material and organic complex systems also apply to cities. In fact, many in the CTC community were (and still are) physicists or mathematicians running their models on data about cities.

Similarly to the founding complexity theories, each complexity theory of cities sheds light on different complexity properties of cities (Portugali 2011): *dissipative cities* emphasizes the link to the environment, *synergetic cities* the bottom-up interaction between the urban agents and the top-down 'slaving principle,' *fractal cities* looks at the fractal structure and morphology of cities, and so on.

But there is a dilemma in the current state of CTC for cities are artifacts: A city is a large-scale artificial built environment, composed of smaller scale artifacts such as buildings, roads, bridges and, parks, each of which is composed of still smaller artifacts—and so on; and, artifacts are essentially simple systems. Some artifacts, such as supercomputers, are very complicated, but are nonetheless essentially simple systems (for further information about cities as complex systems see Batty 2005; Portugali 2000, 2011): Buildings, roads, bridges, neighborhoods, cities or even metropoles do not—by themselves—interact either with their environment or among themselves. So what is it that makes the artifact city, inherently a simple system, into a complex one?

1.2 Cities as Dually Complex Systems

The straightforward answer to the question is that the city as an artifact becomes a complex system due to its urban agents. But how do these agents fit into the definition of the city as a system? Cities are composed of material components and organic components, including humans. As a set of material components alone, the city is an artifact: a simple system. However, seen as a set of human components—the urban agents—the city is a complex system. The city, of course, is both. It is thus a *hybrid simple-complex system*, and it is the urban agents that by means of their interaction—among themselves, with the city's material components and with the environment—transform the artifact city into the complex artificial system city.

But the city is a dual complex system in several other ways. First, as a complex artificial system, the city emerges out of the interactional activities of its agents. But once it emerges, its structure and dynamics affect (or "enslave," in the language of synergetics) the behavior of its agents and so on in circular causality—a process that in the domain of social theory is termed *socio-spatial reproduction* (Portugali 2000, 2011). In other words, the city is a large-scale collective and complex artifact that, on the one hand, by means of the activities of its inhabitants and users (the urban agents), interacts with its environment, while on the other, as a consequence of its size, functions as an environment for the large number of people that live and act in cities. This latter property of cities is becoming increasingly prominent as the proportion of people living in cities grows; specifically so in the last century that has witnessed the fastest population growth in human history and the fastest urbanization processes with the result that, for the first time, more than 50 % of the world population lives in cities (Wimberley et al. 2007). The city in this respect is a *complex artificial environment* (Portugali 2011, Chap. 11).

Second, artifacts are not just the outcome of human interaction but are also *the media of interaction*; artifacts such as texts, cities, buildings or roads are *external representations* of ideas, intentions, memories and thoughts that originate and reside in the mind of urban agents—that is to say, of *internal representations*. However, just as artifacts cannot directly interact among themselves, neither can ideas, thoughts, intentions, plans and other internal representations. They interact by means of the externally represented artifacts, be they texts, clothes, buildings, neighborhoods or whole cities and metropoles. Urban dynamics thus involve ongoing interaction between external and internal representations. The notion of SIRN (Synergetic inter-representation networks) captured this interaction between internal and external representations (Portugali 2011, Chap. 7).

Third, as discussed at length in CCCity (*Complexity, Cognition and the City*, Portugali 2011), the city as a whole is a hybrid complex system and each of its agents is also a complex system. This is not the case with material complex systems in which complexity is a property of the global system but not of the parts. Organic complex systems are different, as each of their parts is a complex system too; however, since the parts of organic complex systems (such as plants or animals) are subject to the slow process of natural Darwinian evolution, the short-term feedback effect of the global system (such as a flock of birds or fish) on the parts in negligible and thus the duality of such systems can be ignored. The situation is different with respect to cities as hybrid complex systems, as their agents are simultaneously subject to two evolutionary processes: very slow natural evolution, which they rarely witness in their lifetime, and very fast cultural evolution, whose effect on the urban agents in instantaneous—urban agents have to adapt to the quickly-changing urban environment. But *how* do they adapt to fast cultural changes? By means of their cognitive capabilities! The implication is that we have to include the cognitive capabilities of the urban agents in our treatment of the dynamics of cities.

In line with this, *CCCity* was a first attempt in this direction with emphasize on one cognitive capability—the capability of *cognitive mapping*. In it I propose that the behavior of the complex parts of the city—the urban agents—is mediated by, and thus strongly influenced by, their cognitive maps of the city. This is significant because studies on the "systematic distortions in cognitive maps" (Tversky 1992; Portugali 2011, Chap. 6) have shown that "the map is not the territory." In other words, cognitive maps are not one-to-one representations of the environment; rather, they are often systematically distorted in several specific ways. In what follows, I aim to direct attention to a second cognitive capability by means of which urban agents adapt to fast cultural changes, namely, their relation to *time* and by implication to planning and design. The urban agents—the parts of the complex system city—are parts of a special kind: they are typified by *chronesthesia*, the ability to mentally travel in time to both the past and future. Unlike cognitive mapping that typify many species including humans, the cognitive property of chronesthesia seems to be unique to humans (Suddendorf and Corballis 2007).

1.3 Chronesthesia and the City

The notion of *Chronesthesia*, also known as *mental time travel* (MTT), was originally hypothesized by Tulving (1983) with respect to *episodic memory*. It refers to the brain's ability to think about—"mentally travel" to—the past, present, and future. The notion is associated with several domains of cognition. One example is *cognitive planning*, a domain that studies the cognitive ability of humans to think ahead to the future and to act accordingly now (Miller et al. 1960; Das et al. 1996; Morris and Ward 2005; Portugali 2011, Chap. 13). A second domain is the study of *prospective memory*, which explores human ability to remember to perform an intended or planned action (McDaniel and Einstein 2007; Haken and Portugali 2005). A third domain concerns cognitive processes that support *episodic simulation of future events* (Schachter et al. 2008). Recent neurological studies further indicate that certain regions in the brain "were activated differently when the subjects thought about the past and future compared with the present. *Notably, brain activity was very similar for thinking about all of the non-present times (the imagined past, real past, and imagined future)*" (Nyberg et al. 2010). "These processes together," write Schacter et al. (2008), "comprise what we have termed "the prospective brain," whose primary function is to use past experiences to anticipate future events."

The suggestion here is that the planning and design of artifacts are direct manifestations of humans' chronesthetic memory. Humans are, in this respect, natural planners and designers. And not only do humans have this ability to mentally travel in time, and are thus capable of MTT, but they also *cannot not mentally travel in time*; studies show that "unlike other animals," human beings spend about half of their waking hours "*thinking about what is not going on around them, contemplating events that happened in the past, might happen in the future, or will never happen at all*" (Killingsworth and Gilbert 2010). So much so, that "stimulus-independent thought" or "mind wandering" has been shown to be the brain's default mode of operation (Raichle et al. 2001; Buckner et al. 2008).

This tendency also includes urban agents—they too are natural planners and designers and as such *cannot not* plan or design.[1] The natural tendency to plan and

[1]Obviously not all human action and behavior is planned and we thus need to distinguish between *planned behaviors* and *un-planned behaviors*.

design, as well as the fact that we seem unable to not do it, shed light on two properties of cities which are discussed below. The first concerns urban planners and designers in relation to the urban planned and designed, and the second concerns the nature of the urban landscape.

1.4 Planning and Design Behavior

Often the various cognitive capabilities are associated with distinct forms of behavior. For example, the ability of animals and humans to construct cognitive maps (Tolman 1948) is termed as *cognitive mapping* (Downs and Steas 1973, 1977), while their related ability to find their way informs *wayfinding behavior* (Golledge 1999). Related to both is *exploratory behavior*, referring to the animal (and human) tendency to start a process of exploration when introduced to a new environment (Drai et al. 2001; Eilam and Golani 1989; Blumenfeld-Lieberthal and Eilam 2016). In a similar way, I have shown (Portugali 2011) that the various cognitive planning capabilities of humans entail a distinct form of behavior that can be called *planning behavior.* To this I now add that design capabilities are also associated with planning capabilities and one may speak of *design behavior* as well as planning behavior.

The notions of planning behavior and design behavior lead to a new view of the city and the urban landscape: When observing a city, urban agents perceive not only the existing urban landscape of visible building, streets, parks an the like, but also *expected* buildings and other urban elements, that is, they see an urban landscape composed of urban entities that have been planned or designed but do not yet exist and might never be realized.[2] As a consequence, agents' behavior and action in cities is determined not only by responses to the present city, but by uncertain plans that have not yet materialized—that is, by what they and other agents expect, plan or intend to do.

Out of this observation a twofold question arises: How can we describe the city as a landscape of potentialities (of uncertain plans that have not yet materialized) and the way urban agents behave in it? I suggest we can do so by means of an interplay between two forms of information: Shannon's information and semantic information. This interplay has recently been termed *information adaptation* (Haken and Portugali 2015).

[2]This might sound bizarre, but note, firstly, that agents' behavior in the stock markets, for example, is very similar to this perception of the planned/designed city in that it is largely dominated by expectations about uncertain future events—expectations that affect our immediate future whether they come to pass or not.

1.5 Information Adaptation and the City

1.5.1 Shannon's Information Theory

Information theory, developed by American mathematician Shannon (1948), deals with the capacity of *communication channel*s to transmit *signals* of all kinds, where a 'communication channel' might be anything from a telephone or a computer to a text, picture, dance or a bird's song, while 'signals' might similarly range from the "*bip, bip*" of Morse code to the letters of a text in any language, the notes of a melody, the colors of a painting or the behavioral body movements of a human or animal. This capacity depends on the statistical properties of the signals, but not on their meaning. In this sense, channel capacity is a fixed physical quantity in each specific case, devoid of meaning. Shannon suggested several notions of information quantity. The most common is Shannon's *information bits* (Shannon and Weaver 1949), which can be defined as follows:

$$I = \log_2 Z \tag{1.1}$$

where Z is the number of possible states the system can take.

An example of its use is the case of rolling a dice, where Z = 6 and I (the quantity of Shannonian information enfolded in the process of rolling of a dice) is about 2.5 bits. The more general definition of information bits, however, is Shannon's famous formula that defines information in terms of entropy:

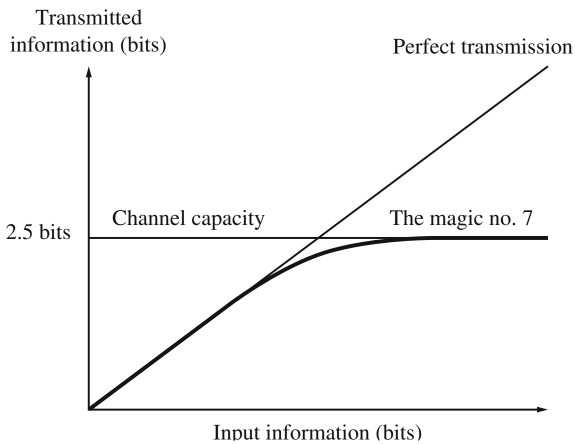
$$i = K \sum_k p_k \ln p_k, \tag{1.2}$$

This definition allows us to calculate the (information) entropy $\boldsymbol{i}$ of any signal with a known $\boldsymbol{p}$, that is, the relative frequency (or probability) of distribution of symbols, distinguished by the index k.

1.5.2 The Face of the City Is Its Information

Since Shannon launched information theory with his seminal paper (1948, for a review see: Gleick 2011), the theory has provided, and still provides, the foundation to any discussion of information; it was and still is central to the development of computer technology and science, communication and information sciences, and cognitive sciences. One early application in cognitive science was Miller's famous 1956 study: "The magic number seven plus or minus two: Some limits on our capacity for processing information." As the title indicates, Miller proposed evidence demonstrating that there is a limit the human capacity to process information in short term memory; it is about 2.5 bits (see: Fig. 1.2).

Fig. 1.2 The relations between input information and transmitted information according to Miller (1956): up to about 2.5 bits of information there is perfect transmission; beyond that threshold, transmitted information levels off. (*Source* Portugali 2011, Fig. 1.1)



A second set of cognitive applications was in Gestalt theory, in which it was used to show that "*good gestalt* is a figure with some high degree of internal redundancy" (Attneave 1959, 186). From the latter follow two implications: First, different (abstract or specific) forms transmit different quantities of information that can be measured by means of Shannon's information bits; Second, the quantity of information conveyed by an abstract or specific form "is a function not of what the stimulus is, but rather of what it might have been" (Garner 1974, 194). Thus, in Fig. 1.3, rotating the circle four times by 90° conveys zero information bits, as the circle remains the same whatever its rotation. A circle in this respect is "a good gestalt." On the other hand, rotating an L-shape form four times by 90° conveys two information bits ($i = \log_2 4 = 2$), as 90° rotations could give rise to four different forms. The first implication provided the starting point for the application of Shannonian information to cities (Haken and Portugali 2003), while the second property is key to the usage of information in this paper as a landscape of potentialities.

In "The face of the city is its information," we show that different elements in the city, as well as different configurations of these urban elements, afford the perceiving urban agents different levels of information that can be measured by Shannon's information bits (Haken and Portugali 2003; Portugali 2011, Chap. 8). Thus, as shown in Fig. 1.4, when all buildings in a street are similar to each other (top line), information *i is low;* when they are different (second line down), *i is high* but hard to memorize, because of Miller's "magic number seven"; when landmarks (i.e. high rises) are added to a street with otherwise identical buildings, at different

Fig. 1.3 Rotating a circle conveys zero bits of information; rotating an L-shape conveys two bits

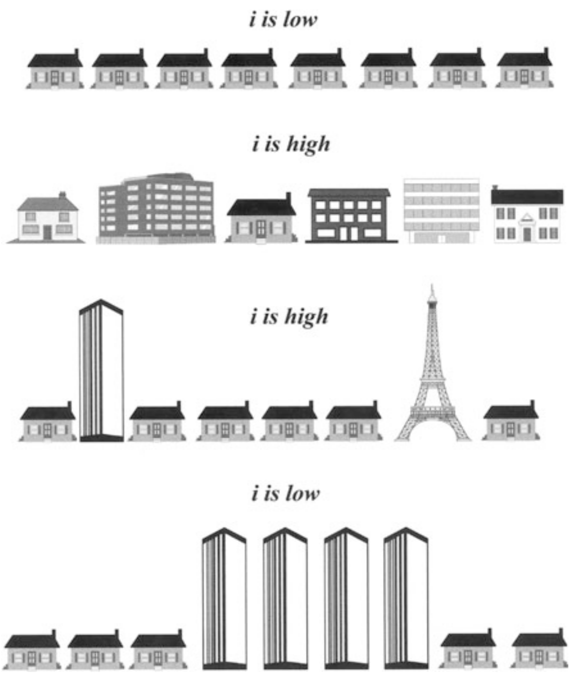


Fig. 1.4 When all buildings are similar (*top line*), *i is low;* when they are different (*second line down*), *i is high* but hard to memorize; when landmarks are added, but separated from each other (*third line down*), *i is high*; and when they are grouped (*bottom line*), *i is low*

Fig. 1.5 The tower house at Piazza del Campo, Siena (*left*), versus the tower houses of San Gimignano (*right*)

points (third line down), *i increases*; and when the high rises are grouped (bottom line), *i decreases*.

The last two cases can be exemplified by a comparison between the towns of Siena and San Gimignano, both in Tuscany (a region of Italy). In Siena, the tower overlooking Piazza del Campo (Fig. 1.5, *left*) acts as a landmark that clearly indicates the central square of the town. In San Gimignano (Fig. 1.5, *right*), the towers are too many and too similar, and as a consequence lose their meaning as landmarks within the city. However, as a group, they have become a symbol of the city of San Gimignano as a whole, distinguishing it from the more ordinary medieval typology of a single central tower, such as Siena's.

1.5.3 Semantic Information Enters in Disguise

"The face of the city is its information" also discusses the relations between Shannonian information, semantic information and complexity from the perspective of Haken's *Information and Self-Organization* (1988/2003). Given a receiver modeled as a dynamical complex system that has a number of attractor states, semantic information is defined as a message that carries meaning in the sense that it causes a specific effect on that receiver. The messages (signals) carrying semantic information are considered different if they cause the dynamical system to reach different attractor states. One can visualize such a dynamical complex system as a ball resting on a peak in a hilly landscape where the valleys represent basins of attraction into which, as a consequence of some initial conditions, the ball might roll (Fig. 1.6). Semantic information can thus be likened to a landscape of attractors representing different potentialities carrying different meanings.

We then claim that in the domain of cognition, semantic information enters in disguise into the definition of Shannonian information. ("In disguise", because Shannon's information is assumed to be independent of semantics). Intuitively, and with respect to Fig. 1.6, we can say that semantic information determines the landscape of hills and valleys, which from the point of view of Shannonian information defines the various possibilities open to the system (the ball on top of the hill). Mathematically this is so since the choice of the index $\boldsymbol{k}$ in (1.2) above requires the

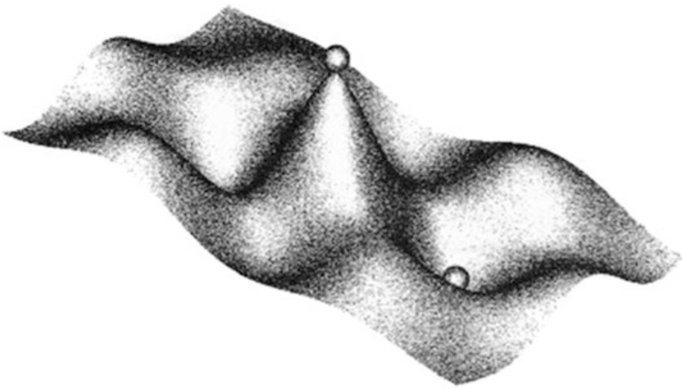


Fig. 1.6 Semantic information as a landscape of potentialities. (*Source* Haken 2004, Fig. 4.7. See also: Haken and Portugali 2011, Fig. 7.1)

categorization of urban elements such as buildings into, say, building styles (modern, postmodern and so on), functions (such as residential, offices, or industrial) or a combination of the two. Such a categorization implies giving *meaning* to different urban elements or, in other words, *applying semantic information.*

1.5.4 Information Adaptation

Semantic information thus participates in the determination of Shannonian information; but what about the inverse relations? Does Shannonian information affect, or participate in, the determination of semantic information? In our recent monograph on the topic (Haken and Portugali 2015) we explored the relations between Shannonian and semantic information more deeply. The result of this exploration is the notion of *information adaptation* (the title of the monograph) that emerges out of *the interplay between Shannonian and semantic information* (its sub-title). More specifically, we show that in cognition, Shannonian and semantic information are interrelated as two aspect of a process of information adaptation in which (as we've seen above) Semantic information controls Shannonian information, while Shannonian information generates semantic information.

A case in point is the process of vision, recently summarized by Kandel (2012) and modeled by Poggio and Serre (2013), on the basis of Hubel and Weisel's seminal studies (1959, 1962, 1965) and on Livingstone's more recent findings (2002), as well as the work of Freiwald and Tsao (2010). The process is illustrated in Fig. 1.7. Data from the environment is first analyzed (or "deconstructed," in Kandel's words) by the mind/brain, in a bottom-up manner, into local information of lines, corners and similar elements; this local information triggers a top-down

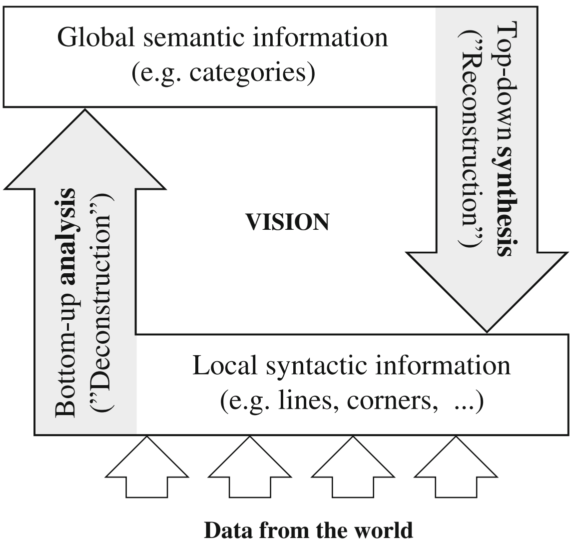


Fig. 1.7 A schematic description of the process of vision: data from the world is first analyzed by the brain, in a bottom-up manner; this local information triggers a top-down process of synthesis that gives rise to global information—that is, to seeing and recognition (See Haken and Portugali 2015)

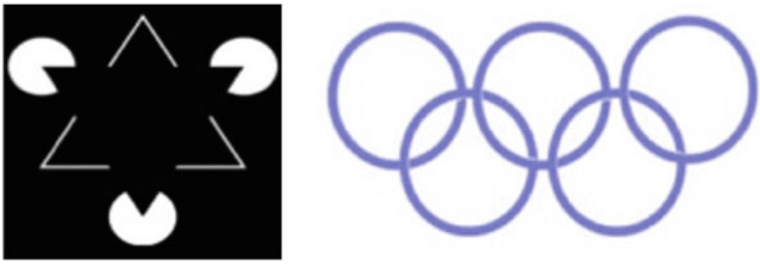


Fig. 1.8 *Left* the Kaniza triangle illusion. *Right* the "Olympic rings" illusion

process of synthesis ("reconstruction," for Kandel) that gives rise to global information—what we experience as seeing and recognition. In the synthetic process, global semantic information, such as categories, interacts with quantitative Shannonian local information. In this interaction, Shannonian information is adapted to semantic information by information inflation or deflation.

An example of information adaptation implemented by means of *information deflation* is the 'Kaniza triangle' illusion (Fig. 1.8, *left*), in which we see lines where there are none; our brain adds virtual line where no lines exist to mark out intersecting triangles. The "Olympic rings" illusion (Fig. 1.8, *right*) serves as an example of information adaptation implemented by means of *information inflation*: we see five circles in superposition and overlook the many geometric forms of which this figure is also be composed.

1.5.5 Information Adaptation in Behavior

In our recent monograph on information adaptation (Haken and Portugali 2015), our focus was on cognitive processes such as perception, learning and pattern recognition. Here I want to draw attention to an additional form of information adaptation related to cognition, namely information adaptation by means of *behavior*. I would also like to link information adaptation by means of behavior to 'chronesthesia and the city' and the implied planning and design behaviors discussed in Sect. 1.3. My suggestion is, first, that every urban element conveys *objective* or *syntactic* Shannonian information that refers to its potential possible states or uses of which, at each given time, one is materialized. As noted by Weaver (Shannon and Weaver 1949) Shannonian information can be (intuitively) interpreted also as a measure of "freedom of choice". For example, if a given element in the city is legally defined as a warehouse, it can be used in one way only which implies no choice; its Shannonian information is thus 0 bits:

$$I = \log_2 1 = 0 \text{ bits}$$

Second, I suggest that every urban element conveys *subjective* semantic information referring to the specific way each urban agent perceives that urban element.

For example, for a poor artist desperately looking for a place to live and to work, the warehouse conveys different meanings than it might to another urban agent, as a consequence of the many ways the artist could potentially use it: as an apartment, a studio and even a shop. Its semantically determined Shannonian information will now be about 1.5 bits:

$$I = \log_2 3 \approx 1.5 \text{ bits}$$

How does the artist urban agent come to perceive the warehouse urban element in the creative way described as above? The answer is simple: urban agents are influenced by a combination of imagination, pressing needs and, often, precedents—such as remembering reading or hearing that someone did something similar. More specifically, urban agents can perceive the potential of an urban element as a consequence of chronesthesia—the property that our artist, like every other urban agent, *cannot not* mentally travel in time. Because the artist travels back to the past to "see" precedents, and forward to the future to "see" urban states that do not yet exist, s/he can act accordingly. In short, subjective semantic information is created as a consequence of the fact that urban agents are cognitive planners and designers.

1.6 Lofts, Balconies and Butterfly Effects

The creative planning described above is, of course, the story of lofts in New York, London and other big cities around the world. As described by Kwartler (1998), in New York City, *ad hoc conversion of lofts in SoHo by individuals began in the 1960s, illegally and in contravention of both the New York City Zoning Resolution and Multiple Dwelling Law. Subsequently, this ad hoc activity was legitimized by revisions to both sets of regulations in 1982.*

A similar scenario unfolded in Tel Aviv (and subsequently across Israel) in what has been described as the "butterfly effect of Tel Aviv balconies" (Portugali 2011; Portugali and Stolk 2014). Here, back in the late 1950s or early 1960s, an anonymous urban agent perceived the future state of his/her open balcony as a half room, planned a set of activities for it, designed the specific form of this half room and implemented his plan and design. As in the case of lofts, it took several decades before the planning authorities legitimized closed balconies; in fact in Israel (and by extension Tel Aviv) this happened very recently—during the year 2010.

However, what made the New York and Tel Aviv planning authorities change the planning laws of their cities was not the lofts or closed balconies in themselves, but rather the processes of mass self-organization that followed the innovative actions of the heroes of our stories—the two anonymous pioneering urban agents. From the perspective of the city as a complex system, these self-organizing and legitimization processes are the really interesting stories: Following the first loft conversion and closed balcony, the neighbors and friends of our two heroes could see, appreciate and in time imitate the new creative invention. From that moment on a self-organized process of space-time diffusion of the innovative urban element started, very much in line with Hägerstrand's theory of *Innovation Diffusion as a Spatial Process* (1967).

In terms of information adaptation I would add that the first lofts in New York City and the first closed balconies in Tel Aviv have altered the semantic information of the urban landscapes of the two cities: urban agents no longer see an industrial district with warehouses or residential buildings with balconies, but potential lofts and half rooms. These alterations in the potential (not yet existing) semantic and Shannonian information content of the urban landscape affected the location decisions and actions of a growing number of urban agents who started to build lofts and to close balconies; as a consequence land and property prices went up, and the whole urban dynamic changed. The legalization of lofts in New York two decades after they first emerged and of closed balconies in Tel Aviv four decades after their first appearance, was a consequence of these complex, collective, self-organized effects—of the fact that they became integrative components of their cities' *order parameter*, that is, dominant and dominating urban form. (For a formal definition of 'order parameter' see Portugali 2011).

My suggestion is that this chronesthetic tension between Shannonian and semantic information—between the existing state of urban elements and their semantically determined Shannonian information—is the *generative order* of the city as a complex, cognitive self-organizing system; that there are many other, less prominent or well-known urban events than the conversion of lofts and balconies, involved in continually changing urban dynamics; that the above tension is the generator of the common saying in CTC that cities emerge and change from the bottom up, out of the interaction between their agents; that as complex systems, cities are always in a far-from-equilibrium state, and that they change by means of self organization.

1.7 Planners and Designers versus the Planned and Designed

If, as a consequence of chronesthesia and cognitive planning and design, urban agents are natural planners and designers, resulting in the kind of self-organizing cities discussed above, we need to rethink the definition of 'urban planner': What are we to do with the prevalent distinction drawn between professional city planners and designers and the rest of the city's inhabitants? Theories of urbanism, planning and design as developed since the early twentieth century tend to treat planning and design as external interventions in an otherwise spontaneous urban process. The structure of cities, according to this view, is seen as an outcome of bottom-up spontaneous processes, on the one hand, and top-down planning and design interventions, on the other. Bottom-up planning or design processes in cities are rarely qualified as 'design' or 'planning'. Notions such as "organic cities" or "unplanned cities" thus refer to exceptions that in fact prove the rule. This perception of planning and design typifies also most CTC, for which the central question is how to plan and design cities in light of their nature as self-organizing systems.

Our own studies about the complexity of cities in relations to planning and design take a different view. We propose that, due to the property of nonlinearity that characterizes the city as a complex system, the planning or design action of a single non-professional urban agent, planner or designer (such as any inhabitant of the city) often affects the city much more than the plans and designs of professional planners—the city's official planning team. The cases of lofts and closed balconies discussed above are prominent examples. Taken in conjunction with the view that urban agents are natural planner and designers, we see each urban agent as a planner or designer at a certain scale, while the urban dynamics as a whole are essentially the product of ongoing interaction between a large number of urban agents at various scales (for further discussion see: Portugali 2011, Chap. 15). This non-linear view of how the complexity of the city is continually produced removes the distinction between bottom-up urban agents' behavior and top-down planning and design intervention.

1.8 Toward a Unified Field of Study

So, what makes cities complex? The answer to this question is simple: urban agents. These urban agents have specific cognitive capabilities—they are mental time travelers—and thus natural planners and designers, making cities complex, or rather, dually complex environments. The conjunction between complexity, cognition, planning and design discussed in this paper indicates a potential for the emergence of a new field of study in which planning and design are not external interventions in an otherwise spontaneous and complex urban process, but rather integral elements in its dynamics.

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Chapter 2
Evolving a Plan: Design and Planning with Complexity

Michael Batty

Abstract Producing physical plans that manipulate urban form and function to generate optimal designs with respect to an affected community is a many-stage process of resolving inherent conflicts between those who represent the interests of the community. Here we introduce a class of decision models that involve resolving conflicts between a series of opinions that differ from one another and are associated with a set of agents who act as designers. These opinions are expressed as differing interest and control in factors that influence the design and these are articulated as spatial plans based on the suitability or desirability of different map locations for physical development. We define a set of agents who motivate the process and whose interactions which involve resolving their conflicting opinions, are used to pool opinions where, at each stage, some degree of resolution takes place. Ultimately because every opinion relates to every other through the network of relations that bind agents together, a consensus is reached that can be interpreted as a process of weighted averaging whose formal properties mirror the operation of a first-order Markov chain. The elaboration of this process that we invoke here is based on a process of exchange due to Coleman (Foundations of Social Theory. Belknap Press, Cambridge, MA, 1994) in which we characterise the problem as one of resolving conflicts between agents which we call the primal or differences between factors in terms of opinions which we call the dual. We define several variants of this process and then demonstrate this for a semi-real 'toy' problem of land development in the heart of London where a small set of stakeholder agents have different degrees of interest and control in a small set of land and building sites (parcels). In terms of the model, we show how the problem is already in equilibrium if interest and control are the same and this provides a benchmark for differences between interest and control which characterise the actual problem. We conclude with proposals for making the model more realistic and extending it to deal with problems where conflicts are only partially resolved or not resolved at all.

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2.1 The Complexity of Design: Evolving Plans Through Opinion Pooling

Design which we consider here as the arrangement of physical forms that satisfy some functions in an optimal or best way, is seldom accomplished immediately in one step. Some argue that good design can be traced to moments of instant inspiration and insight but these are rare and in any case when we are dealing with forms whose function is to enable others to meet their needs, design is usually accomplished in some iterative manner, whether the designer be a lone individual or as is more likely, several individuals, a collectivity, a team, any group working together. In our context where we are focussed on physical forms that range from buildings to landscapes, urban morphologies, and regions, design is very much a communal activity which involves resolving different viewpoints about what constitutes a best solution. In this sense, design is sequential, perhaps even based on a process of argumentation, and this is particularly so where the forms being designed have wide and powerful interests and control involving many stakeholders whose context is often political. In fact, in urban planning, the language of design is often based on defining solutions as plans or policies and although they usually have physical and spatial implications, there are many non- or a-spatial features that bring the process directly into the political and social arena. In this sense, design is inherently complex and the processes that characterise complex systems provide useful analogies.

In this chapter, we will introduce a model of design as a process of evolution, where the aim is to generate design solutions that resolve conflict between stakeholders. Models for this kind of conflict resolution go back 60 years or more (French 1956; Harary 1959) and involve the notion that different opinions about the best design associated with the stakeholders, need to be resolved in some way, leading to a compromise or consensus. The process we will present has often been compared to Markov averaging which produces a solution as a weighted average of the initial opinions as to the best design. This process has quite tractable and rather simple statistical properties (de Groot 1974; Kelly 1981) but more recently, a new wave of interest in this model has characterised it as ‘opinion pooling’ where the focus is much more on generating equilibria using various forms of computation such as flocking (Blondel et al. 2005; Motsch and Tadmor 2014). There are also social network interpretations which link these ideas to network science (Jackson 2011) and the model is also being explored in the study of opinion dynamics (Jia et al. 2013; d’Errico et al. 2014).

We will develop these ideas of opinion pooling on the basis of predicting the form of the networks that tie together various elements of the problem that different opinions are associated with. These networks can be generated from correlations between the opinions of the actors, agents or stakeholders—terms we will use interchangeably—with higher correlations in general being associated with stronger ties between actors. In an equivalent way, we can consider correlations between the elements making up an opinion across the agents and in this way consider that networks can be formed by concatenating these bipartite relations between agents and the elements forming their opinions. In this way, we will draw on ideas from exchange theory specifically introducing Coleman's (1994) model of collective action which represents an unpacking of the more aggregate French-Harary opinion pooling models noted above.

We will thus articulate the problem of choosing a plan in terms of how a group of ***agents*** relate to a series of ***factors*** in which the agents have varying opinions reflecting the degrees of interest in and control they have over the factors they consider important to the best plan. The factors imply something about the plan which is defined in terms of spatial locations. It might, for example, be defined in terms of the relative weights that agents ascribe to factors relevant to the plan or to different plans themselves that agents consider define their interest and control. In our subsequent exposition, we will present different conceptions of the problem defined in terms of different agents and different factors. In this sense, our problem is conceived in terms of the relationships between the social system defined through the agents and the spatial system defined through the factors. We might even consider the rules that define how agents behave socially as the 'genotype' of the problem and the spatial factors as the 'phenotype' but there the analogy ends. It only serves to show that the system can be thought of as a social collective based on relations between agents defined through spatial factors or as a system of relations defined across spatial factors with respect to social agents.

To summarise, agents relate to plans with respect to factors that affect the plan. If we define these consistently, then we can measure the relationships between agents —as a kind of social network—through their varying interest and control over factors. This defines the ***primal*** problem for which there is a natural ***dual*** based on the relations between spatial factors—a kind of spatial network but not in locational terms—through the relative coincidence of interest and control by agents over factors. In the sequel, we will elaborate this conception in several different ways first by introducing a generic framework based on social exchange, namely Coleman's (1994) theory of collective action. We use this framework to define many different variants of the plan-design problem and once we have elaborated its implications, we will produce a key simplification of the structure which pertains to thinking of factors as partial solutions to the planning problem—different plans— which in turn are defined as physical maps. In this way, the framework connects up to plan-design problems which lie at the basis of geo-design. These in turn build on older ideas about map overlay analysis which is a cornerstone of GIS (McHarg 1969; Steinitz et al. 1976; Steinitz 2012) and we will trace these links to spatial averaging in the sequel.

2.2 Social Exchange: A Theory of Collective Action

We first define a set of n agents who each have a degree of interest $\mathbf{X}$ as well as a degree of control $\mathbf{C}$ in a set of m factors. An agent may have a very low degree of interest in a factor but a high degree of control over it and vice versa, and these differences between interest and control define the relative interaction between agents with respect to factors as well as the relative interaction between factors with respect to agents. The first conception we refer to as the ‘primal problem’ and the second the ‘dual’. This is equivalent to thinking of the primal as being soluble through interactions between agents over factors and the dual as interactions between factors with respect to agents. To give this some formal meaning, we first consider the interest which each agent i has in a factor j as an $n \times m$ matrix $\mathbf{X}$ which we define as

$$\mathbf{X} = \begin{bmatrix} X_{11} & X_{12} & X_{13} & \dots & X_{1m} \\ X_{21} & X_{22} & X_{23} & \dots & X_{2m} \\ X_{31} & X_{32} & X_{33} & \dots & X_{3m} \\ \cdot & \cdot & \cdot & & \cdot \\ X_{n1} & X_{n2} & X_{n3} & \dots & X_{nm} \end{bmatrix}, \quad \sum_{j=1}^{m} X_{ij} = 1, \quad \forall i = 1,2,3,\dots,n. \tag{2.1}$$

The matrix of interests is structured in probability form as a stochastic matrix where each element X_{ij} is the proportion of interest that an agent i has in a particular factor j. An analogous stochastic matrix can be defined for the degree of control which is an $m \times n$ matrix $\mathbf{C}$ which we define as

$$\mathbf{C} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \dots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \dots & C_{2n} \\ C_{31} & C_{32} & C_{33} & \dots & C_{3n} \\ \cdot & \cdot & \cdot & & \cdot \\ C_{m1} & C_{m2} & C_{m3} & \dots & C_{mn} \end{bmatrix}, \quad \sum_{k=1}^{n} C_{jk} = 1, \quad \forall k = 1,2,3,\dots,m, \tag{2.2}$$

where C_{jk} is the degree of control over a factor which each agent exercises. Note that the two matrices are defined as being the transpose of one another with respect to agents and factors so that we can relate them directly in the manner used below.

We define the primal problem as one where the interaction between agents is formed by correlating the degree of interest with respect to the degree of control between any two agents. We thence define the probability of interaction between any two agents i and k as the $n \times n$ stochastic matrix $\mathbf{P}$ defined as

$$\mathbf{P} = [P_{ik}] = \sum_j X_{ij} C_{jk}, \sum_k P_{ik} = \sum_k \sum_j X_{ij} C_{jk} = \sum_j X_{ij} \sum_k C_{jk} = 1, \tag{2.3}$$

and this is the key set of relative interactions that define the primal problem. The dual problem is defined in analogous terms as the pattern of interactions between the factors formed as the correspondence between the degree of control and interest across the profile of the agents. We define the probability of interaction between any two factors j and ℓ as the $m \times m$ stochastic matrix $\mathbf{Q}$ defined as

$$\mathbf{Q} = [Q_{j\ell}] = \sum_k C_{jk} X_{k\ell}, \sum_\ell Q_{j\ell} = \sum_\ell \sum_k C_{jk} X_{k\ell} = \sum_k C_{jk} \sum_\ell X_{k\ell} = 1. \quad (2.4)$$

These interactions compose a dual problem which is easily seen as being entirely consistent in formal terms with the primal. If we define processes of consistently resolving conflicts between interest and control with respect to the agents or the factors—on the primal or the dual—then we will be able to generate a consistent set of power relations that are reflected in the solutions generated from (2.3) and (2.4).

Essentially the plan-design problem can be thought of as a process of resolving the differences between interests and control with respect to the agents or with respect to the factors. In this sense we can define a process of conflict resolution on the primal or dual problems with one following from the other. Let us illustrate this for the primal problem. Imagine that we begin with an arbitrary distribution of resources across the agents which is the $1 \times n$ vector $\mathbf{r}(0)$ which we can normalise as $\sum_i r_i(0) = 1$. Now if we assume that the agents examine the resources that other agents have and thus rationally pool them first according to their collective interest and then their control, the agents produce new allocations of resources called $\mathbf{r}(1)$. In terms of the interaction matrix between agents which relates to the relative importance of communications based on their interest and control, this can be written as $r_k(1) = \sum_i r_i(0) P_{ik}$ which in matrix terms is $\mathbf{r}(1) = \mathbf{r}(0)\mathbf{P}$.

Now this is a Markov process with very well defined properties. The resources vector will converge to a unique equilibrium where the relative pooling of resources will stabilise as a function of the interaction matrix (which reflects interests and control). In the steady state, it is easy to show that the resources vector $\mathbf{r}(t+1) \to \mathbf{r}$ as $t+1 \to \infty$; formally this equilibrium is

$$\left.\begin{array}{l} \mathbf{r}(t+1) = \mathbf{r}(t)\mathbf{P} = \mathbf{r}(0)\mathbf{P}^t \\ \mathbf{r} = \mathbf{r}\mathbf{P}^\infty \to \mathbf{r} = \mathbf{r}\mathbf{P} \end{array}\right\}. \quad (2.5)$$

An exactly analogous process occurs if we begin the resources pooling with a vector of the values of the factors that will ultimately compose the plan. Start with a normalised arbitrary $1 \times m$ vector $\mathbf{v}(0)$ where $\sum_j v_j(0) = 1$. Then we produce new values for each factor $\mathbf{v}(1)$ which in terms of the interaction matrix between factors is written as $v_\ell(1) = \sum_j v_j(0) Q_{j\ell}$ or in matrix terms $\mathbf{v}(1) = \mathbf{v}(0)\mathbf{Q}$. This has a steady state equivalent to that in (2.5) reflecting the convergence of values of each factor and giving the importance of each in the final solution where $\mathbf{v}(t+1) \to \mathbf{v}$ as $t+1 \to \infty$; formally this is

$$\left.\begin{array}{l} \mathbf{v}(t+1) = \mathbf{v}(t)\mathbf{Q} = \mathbf{v}(0)\mathbf{Q}^t \\ \mathbf{v} = \mathbf{v}\mathbf{Q}^\infty \to \mathbf{v} = \mathbf{v}\mathbf{Q} \end{array}\right\}. \quad (2.6)$$

Equations (2.5) and (2.6) are interconnected in an entirely consistent way but before we sketch the relationships of these interlinked Markov processes, we need to present a much more intuitive way of illustrating the meaning of these processes that make crystal clear what these processes of social exchange and their equilibrium imply.

It is relatively straightforward to directly connect the two Markov processes. If we multiply the steady state equations for agents $\mathbf{r} = \mathbf{rP} = \mathbf{rXC}$ by the interest matrix $\mathbf{X}$, we can write this as $\mathbf{rX} = \mathbf{rPX} = \mathbf{rXCX} = \mathbf{rXQ}$. However the vector $\mathbf{v}$ in the steady state equation $\mathbf{v} = \mathbf{vQ}$ is unique and therefore it is clear that $\mathbf{v} = \mathbf{rX} = \mathbf{vCX} = \mathbf{vQ}$. In an analogous way, we can multiply by the control matrix $\mathbf{C}$ and from this it is clear that $\mathbf{vC} = \mathbf{vQC} = \mathbf{vCXC} = \mathbf{vCP}$, from which the unique steady state vector $\mathbf{r} = \mathbf{vC}$. Collecting these two results, we can state the equilibrium relations as

$$\left.\begin{aligned} \mathbf{v} &= \mathbf{rX} \\ \mathbf{r} &= \mathbf{vC} \end{aligned}\right\}. \tag{2.7}$$

From this it is clear that there is a much more intuitive explanation of the process of social exchange, of social interaction, which leads to the steady state. We can now iterate on (2.7) by first forming an arbitrary distribution of resources $\mathbf{r}(0)$ or, if we are able to define this, an observed distribution and this generates a distribution of values $\mathbf{v}(0)$, in short, $\mathbf{v}(0) = \mathbf{r}(0)\mathbf{X}$. This essentially means that we take the resources of each agent and we distribute them to each factor in proportion to how much interest they have in that factor; that is the distribution of resources $r_i(0)$ is mapped into the interest in a factor X_{ij} and then this component of the resource $r_i(0)X_{ij}$ is summed over all the agents to find the value that is invested in the factor as $v_j(0) = \sum_i r_i(0)X_{ij}$. Now we have the investment in the factor and we have to consider how much control we have over that factor. This involves us in working out the component of the value in that factor which is controlled by an agent, that is $v_j(0)C_{j\ell}$. We then add up the value that is controlled by each agent in each factor to the total value controlled by the agent in all factors and this gives the amount of resource that is now assigned to the agent, that is $r_k(1) = \sum_j v_j(0)C_{jk}$. If $r_k(1) \neq r_k(0)$ which will always be the case in the initial rounds of iteration, we need to repeat the process, each time indulging our interest and modifying it by exercising our control until the system moves to the unique equilibrium defined above in (2.5)–(2.7).

2.3 Complementary Exchange: Averaging Processes from Markov Chains

Another way of thinking about the processes of moving to an equilibrium distribution of agent resources and factor values is to consider an agent or a factor as changing their opinions or values of their attributes successively in proportion to their resources or values in the following way. For an agent, the initial distribution of resources $\mathbf{r}(0)$ (which is a probability vector) can be interpreted as reflecting the probability that an agent takes on a particular opinion about the problem in question. If we assume a set of agents continually hopping from one state to another, we might even think of the distribution of resources as being the probability that an agent is in a particular state, or rather as the problem is based on agents, the probability of each agent in question having a particular resource. This is continually changing as the agents compare their resources but if we think of agents as states of the system, then the probability of the system being in a particular state is the resource vector $\mathbf{r}(t)$ at any time t. As the pooling of resources moves towards equilibrium, then the steady state vector $\mathbf{r}$ reflects the probability of any agent being in the state associated with that agent. The same process can be considered in terms of the factors and their values which reflect the state of the system that any factor find itself in. This is perhaps a little tortuous but it is the conventional form of a Markov probability process which provides a more traditional interpretation.

At the other extreme, however, we have two complementary processes pertaining to the primal and dual which can be interpreted as the averaging of initial differences within the set of agents, and the set of factors, and these follow the same equilibrium relations that we defined around (2.5)–(2.7). Imagine now that each agent holds a certain attitude about a plan defined as a number in the vector $\mathbf{a}(0) = [a_i(0)]$ which is the value that they start with. Each factor also has a value that we can define equivalently as $\mathbf{f}(0) = [f_j(0)]$. Now consider first the primal process where the agents pool their values on the basis of how they interact with one another which is given by the matrix $\mathbf{P}$. A new set of values at the second iteration of the process is defined from $\mathbf{a}(1) = \mathbf{P}\ \mathbf{a}(\mathbf{0})$ and if we iterate in the normal fashion, it is clear that the set of attitudes will converge to $\mathbf{a} = \lim\ t \to \infty\ [\mathbf{a}(t+1) = \mathbf{P}^{t+1}\ \mathbf{a}(\mathbf{0})]$ and $\mathbf{a} = \mathbf{P}\ \mathbf{a}$. Now as $\mathbf{P}$ is a stochastic matrix, and sums to 1 over its rows, then each agent will move to the same numerical value and this represents a weighted average which is reflected in the structure of $\mathbf{P}$. This is a little easier to see if we note that the steady state matrix $\lim\ t \to \infty\ \mathbf{P}^{t+1}\ = \mathbf{R}$ where each row is the steady state vector $\mathbf{r}$. Thus $\mathbf{a} = \mathbf{R}\ \mathbf{a}(0)$ or $a = a_k = \sum_i R_{ik} a_i(0) = \sum_i r_i a_i(0),\ \forall k$. Each agent thus has the same attitude at equilibrium and it might be said that a consensus has been reached. This is the classic process of Markov averaging first introduced by French (1956), formalised by Harary (1959) and further explored by many others, in particular de Groot (1974) and Kelly (1981) and more recently by Jia et al. (2013) amongst others.

An exactly analogous process pertains to the averaging of factors. If we start with a vector of factor values $\mathbf{f}(0)$, we form $\mathbf{f}(1) = \mathbf{Q}\ \mathbf{f}(0)$ and then through iteration, factor values will converge to $\mathbf{f} = \lim\ t \to \infty\ [\mathbf{f}(t+1) = \mathbf{Q}^{t+1}\ \mathbf{f}(0)]$. As $\lim\ t \to \infty\ \mathbf{Q}^{t+1}\ = \mathbf{S}$, then $\mathbf{f} = \mathbf{S}\ \mathbf{f}(0)$, and the final factor value $f = f_j = \sum_\ell S_{j\ell} f_\ell(0) = \sum_j v_j f_j(0),\ \forall \ell$. Now let us write the equilibrium relations for both these averages as

$$\left.\begin{array}{l} \mathbf{a} = \mathbf{P}\ \mathbf{a} = \mathbf{XCa} \\ \mathbf{f} = \mathbf{Qf} = \mathbf{CXf} \end{array}\right\} \tag{2.8}$$

which can be considerably simplified by noting that as $\mathbf{a} = [a_i] = a,\ \forall i$ and $\mathbf{f} = [a_j] = f,\ \forall j$, then the relations $\mathbf{Ca}$ and $\mathbf{Xf}$ are degenerate in that $\sum_k C_{jk} a_k =$

$a\sum_k C_{jk} = a,\ \forall j$ and $\sum_j X_{ij} f_j = f\sum_j X_{ij} = f,\ \forall i$. Relations equivalent to (2.7) do not hold for the averaging processes. We will explore this convergence in more detail when we use it below to examine how social agents can define solutions to spatial problems through the notion of factors being equivalent to map layers. A full statement of the model is presented by the author (Batty 2013) where there are various additional interpretations of the convergence to a steady state. We assume that the matrices **X** and **C** are defined so that **P** and **Q** are strongly connected which is a basic requirement of articulating the problem in the first place. This implies that every agent is linked to every other agent and every factor to every other factor, directly or indirectly though the networks associated with **P** and **Q**.

2.4 Maps as Factors: Using the Model to Simulate the Map Overlay Problem

We will now focus on the averaging problem where we define the agents as social entities that have an interest and control over a planning solution which they articulate as a set of maps. We will define the series of maps in the $n \times m$. matrix $\mathbf{M}(0)$ as

$$\mathbf{M}(0) = \begin{bmatrix} M_{11}(0) & M_{12}(0) & M_{13}(0) & \dots & M_{1m}(0) \\ M_{21}(0) & M_{22}(0) & M_{23}(0) & \dots & M_{2m}(0) \\ M_{31}(0) & M_{32}(0) & M_{33}(0) & \dots & M_{3m}(0) \\ \cdot & \cdot & \cdot & & \\ M_{n1}(0) & M_{n2}(0) & M_{n3}(0) & \dots & M_{nm}(0) \end{bmatrix}, \tag{2.9}$$

where each agent $i, i = 1, 2, 3, \dots, n$ expresses an initial value that they ascribe to each map cell or location at time $t = 0$ as $M_{ij}(0), j = 1, 2, 3, \dots, m$. In fact the map associated with agent i is strung out as a $1 \times m$ vector whose values define the relative importance that the agents ascribe to the problem. To fix ideas, we might consider each map at this stage to represent the development potential that an agent i ascribes to the location or cell j of the map, with the differences between each map vector in terms of these values as pertaining to differences between agents which need to be resolved as a solution to the problem. The differences between the column map vectors then describe the differences in potential between the agents with respect to a particular map cell or location. In short the process of averaging or compromising is one that irons out these differences according the balance of interest and control that first, the agents have in factors which are now assumed to be individual maps, and second, locations or map cells associated with agents which are location profiles across all agents. These define the primal and dual respectively.

We can now use all the results we have derived to illustrate what happens if the agents resolve conflicts between their different maps through averaging. We will now consider each set of maps $\mathbf{M}(0)$ defined as a row of cells for each agent and its transpose $\mathbf{M}^T(0)$ as a column of cells for each agent. The averaging across agents is based on the process defined as $\mathbf{M}(t+1) = \mathbf{P}^{t+1}\mathbf{M}(0)$ and this converges to $\mathbf{M} = \mathbf{PM}$ while the averaging across cells is $\mathbf{M}^T(t+1) = \mathbf{Q}^{t+1}\mathbf{M}^T(0)$ and this converges to $\mathbf{M}^T = \mathbf{QM}^T$. We can write these equilibrium averages explicitly as

$$\left.\begin{array}{l}\sum_k P_{ik}M_{kj} = M_j, \forall j \\ \sum_\ell Q_{j\ell}M_{\ell k} = M_\ell, \forall k\end{array}\right\}, \tag{2.10}$$

where M_{ij} is the transpose of M_{ji} and vice versa. When we write these transposes explicitly, we simply interchange the rows and columns which are always defined with respect to agents as i and k and maps (factors) as j and ℓ. In fact we can compute these averages directly from knowledge of the steady state resources and values from (2.5) and (2.6) and these are $M_j = \sum_i r_i M_{ij}$ and $M_i = \sum_j v_j M_{ji}$.

Now there is a dramatic simplification of this process when we define the interest agents have in maps and the control they have over maps in terms of the same values they ascribe to the map. That is, we will define the two matrices $\mathbf{X}$ and $\mathbf{C}$ directly from $\mathbf{M}(0)$ and $\mathbf{M}^T(0)$. Then

$$X_{ij} = \frac{M_{ij}(0)}{\sum_\ell M_{i\ell}(0)} = \frac{M_{ij}(0)}{M_i(0)}, \quad \sum_j X_{ij} = 1, \text{and} \tag{2.11}$$

$$C_{jk} = \frac{M_{jk}(0)}{\sum_i M_{ji}(0)} = \frac{M_{jk}(0)}{M_j(0)}, \quad \sum_k C_{jk} = 1. \tag{2.12}$$

Note that $M_i(0)$ is the sum of the rows or the total interest that an agent has in all the maps, that is in matrix terms $\mathbf{M}(0)\mathbf{1}^T$ where $\mathbf{1}$ is the relevant unit column vector, and $M_j(0)$ is the sum of the columns or the total control that all agents vest in a cell of the map, in matrix terms $\mathbf{M}^T(0)\mathbf{1}$. If we now write these sums in their appropriate diagonal matrix, we can write the matrix equations for interest and control as

$$\left.\begin{array}{l}\mathbf{X} = \mathbf{DM} = \begin{bmatrix} M_1^{-1}(0) & 0 & 0 & \dots & 0 \\ 0 & M_2^{-1}(0) & 0 & \dots & 0 \\ 0 & 0 & M_3^{-1}(0) & \dots & 0 \\ . & . & . & \dots & . \\ 0 & 0 & 0 & \dots & M_n^{-1}(0)\end{bmatrix}\begin{bmatrix} X_{11} & X_{12} & X_{13} & \dots & X_{1m} \\ X_{21} & X_{22} & X_{23} & \dots & X_{2m} \\ X_{31} & X_{32} & X_{33} & \dots & X_{3m} \\ . & . & . & & . \\ X_{n1} & X_{n2} & X_{n3} & \dots & X_{nm}\end{bmatrix} \\ C = \boldsymbol{\delta}\mathbf{M}^T = \begin{bmatrix} M_1^{-1}(0) & 0 & 0 & \dots & 0 \\ 0 & M_2^{-1}(0) & 0 & \dots & 0 \\ 0 & 0 & M_3^{-1}(0) & \dots & 0 \\ . & . & . & \dots & . \\ 0 & 0 & 0 & \dots & M_m^{-1}(0)\end{bmatrix}\begin{bmatrix} C_{11} & C_{12} & C_{13} & \dots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \dots & C_{2n} \\ C_{31} & C_{32} & C_{33} & \dots & C_{3n} \\ . & . & . & & . \\ C_{m1} & C_{m2} & C_{m3} & \dots & C_{mn}\end{bmatrix}\end{array}\right\} \tag{2.13}$$

Note that the inverses M_i^{-1} and M_j^{-1} in $\mathbf{D}$ and $\boldsymbol{\delta}$ respectively are inverses of the row and column sums of the original map matrix $\mathbf{M}(0)$. We can now simplify the equilibrium relations directly by substituting these expanded representations of the interest and control matrices into any of (2.5)–(2.7). In fact using (2.7), we can write these as

$$\left.\begin{array}{l}\mathbf{v} = \mathbf{rX} = \mathbf{rDM}(0) \\ \mathbf{r} = \mathbf{vC} = \mathbf{v}\boldsymbol{\delta}\,\mathbf{M}^T(0)\end{array}\right\}. \tag{2.14}$$

If we set $r_i = M_i(0)$ and $v_j = M_j(0)$, then $\mathbf{rD} = \mathbf{1}$ and $\mathbf{v}\boldsymbol{\delta} = \mathbf{1}$ and (2.14) become $\mathbf{v} = \mathbf{1M}(0)$ and $\mathbf{r} = \mathbf{1M}^T(0)$. In short the equilibrium vectors—the relative values of each map and the resources for each agent—are the values invested in each cell of the map by all the agents, and the values invested by each agent in all the maps. This is a very interesting result. It means that if the basic map matrix determines both the interest and control, the system is already in equilibrium, that is, interest and control align exactly. In fact this also implies what is obvious from this exposition, that is, that the differences between interest and control determine the need to compromise. In this sense, we might consider the difference between the final resource and value vectors from a situation where interest and control differ and these simplified vectors a measure of how far from equilibrium a system of interaction such as this one is. In short, the differences $\mathbf{v} - \mathbf{1M}(0)$ and $\mathbf{r} - \mathbf{1M}^T(0)$ determine how far from equilibrium the system is.

There is one last variant of this process that does not rely on defining probability relationships between agents and factor maps through interest and control but simply takes the agent-map matrices and forms social networks based on the relative similarity between agents in the primal problems and map factors in the dual. This is much more akin to the traditional averaging networks first introduced by French (1956) and Harary (1959). Comparing the values that agents ascribe to maps with respect to how similar agents are to one another, we can form the interaction matrix $\tilde{\mathbf{P}} = \mathbf{M}(0)\mathbf{M}^T(0)$. This is a symmetric matrix that gives the strength of connections between pairs of agents and this defines our primal problem. This is in one sense an un-normalised version of the map matrix for the normalised interest and control matrices in (2.11) and (2.12) above. The dual symmetric interactions between map factors which is a comparison of the similarity between any two maps over all agents is given in an analogous way as $\tilde{\mathbf{Q}} = \mathbf{M}^T(0)\mathbf{M}(0)$. From these matrices, we can form stochastic matrices $\mathbf{P}$ and $\mathbf{Q}$ which form the essence of the two probability and averaging processes which define the equilibrium relations associated with the primal and the dual. As above, these can be written in diagonal and map matrix form as

$$P_{ik} = \frac{\sum_j M_{ij}M_{jk}}{\sum\limits_j \sum\limits_z M_{ij}M_{jz}} = \mathbf{DM}(0)\mathbf{M}^T(0), \quad \sum_k P_{ik} = 1, \text{and} \tag{2.15}$$

$$Q_{j\ell} = \frac{\sum_k M_{jk}M_{k\ell}}{\sum_k \sum_z M_{jk}M_{kz}} = \boldsymbol{\delta}\,\mathbf{M}^T(0)\mathbf{M}(0), \quad \sum_\ell Q_{j\ell} = 1, \tag{2.16}$$

with the equilibrium relations now defined as

$$\left.\begin{array}{l}\mathbf{r} = \mathbf{rP} = \mathbf{rDM}(0)\mathbf{M}^T(0) \\ \mathbf{v} = \mathbf{vQ} = \mathbf{v}\boldsymbol{\delta}\,\mathbf{M}^T(0)\mathbf{M}(0)\end{array}\right\}. \tag{2.17}$$

If we assume that the resource and value equilibrium vectors are defined from the normalisation factors in each of the diagonal matrices as

$$\left.\begin{array}{l}r_i \propto \sum\limits_j \sum\limits_z M_{ij}M_{jz} \\ v_j \propto \sum\limits_k \sum\limits_z M_{jk}M_{kz}\end{array}\right\}. \tag{2.18}$$

The matrix equations in (2.17) then simplify to

$$\left.\begin{array}{l}\mathbf{r} = \mathbf{1M}(0)\mathbf{M}^T(0) \\ \mathbf{v} = \mathbf{1M}^T(0)\mathbf{M}(0)\end{array}\right\}. \tag{2.19}$$

As these matrices $\mathbf{M}(0)\mathbf{M}^T(0)$ and $\mathbf{M}^T(0)\mathbf{M}(0)$ are symmetric, it is easy to show that the column sums are the same as the row sums for each relation thus proving (2.18). In fact this is the result that is presented by the author (Batty 2013) for the French-Harary model, the first in the development of this kind of conflict resolution.

At this stage we have presented the essential logic of opinion pooling as it might be dimensioned to a problem where agents have different interests and control in locations specified by a spatial system represented by a map. We have also introduced a set of variants of the collective action model and in the remaining part of the chapter, we will demonstrate how these models might be applied to a semi-real problem of land use allocation in the heart of world city. The model of course can be generalised to any system where there are two sets of characteristics and in fact, most opinion pooling models are non-spatial. But the logic of developing the model in this context is strikingly similar to that used in map overlay analysis in GIS and urban design and this is the focus we will exploit and demonstrate here.

2.5 Applications of the Approach: Competition for Land Use in a World City

To demonstrate how we determine a solution equivalent to evolving a plan from the differing plans of the relevant agents or stakeholders, we have chosen a problem of reconciling different interests in land development in the heart of a world city, London. The area we have chosen is some 5 hectares in size, immediately north of St. Paul's cathedral in an area that for the last 200 years (until quite recently) has been the location of the General Post Office and is now largely occupied by financial services, medical-hospital uses, and private apartments. It is in an area that is undergoing rapid change of use and redevelopment as investors and developers attempt to realise ever more profits from its location in the 'square mile', the financial quarter of London and the borough which is called the 'City'. The pressures on development are huge while the control over what happens is severely constrained by the City Corporation. All this conflicts with the massive amounts of capital that are tied up in the buildings which house some of the world's most prominent financial services.

This application is a caricature of the development process and in this sense, it is a 'toy' example simply to illustrate the nature of the solution process rather than to provide any realistic resolution of conflicts in the area. We will define a limited number of key agents—but only 6 in all—who dominate the scene. In reality, however, there are many more, including groups whose interest originates from issues beyond the area in question. In terms of the way we define the map, we deal simply with the location of 8 land parcels, most containing buildings and we do not consider the streets between the buildings as uses that would change in any way. In fact the land parcels and streets are not assumed to change their configuration in the plan, and this is consistent with the relatively inert structure of land parcels in this part of London, notwithstanding considerable change in the usage of land and in the way it is developed and occupied. We list the agents and the sites that compose the map in Table 2.1 which gives an immediate sense of the nature of the problem.

The area is shown in Fig. 2.1 where the buildings are defined by the numbers in Table 2.1, and some sense of the character of the area is given by the thumbnail pictures showing individual viewsheds in the area which are shown in Fig. 2.2. We will say something about each of the sites or land parcels in the order shown in Table 2.1. Site 1, the Aldersgate Complex, is a large postmodern ziggurat-type building adjacent to the Museum of London at the western end of London Wall (the original Roman wall of the city). The site was redeveloped in the early 1990s and it is unlikely to be changed physically in the next decade although it has recently been reconfigured after the financial crisis and now contains a number of financial services companies in contrast to its previous tenant which was a large law firm. South of this is the building complex that bounds site 5, Postman's Park. On the southern side of the Park is site 3, the 1880 General Post Office building which is now owned

Table 2.1 Agents and sites-land parcels-buildings

$n = 6$	Agents	$m = 8$	Sites-land parcels-buildings
1	City Corporation	1	Aldersgate Complex
2	Residents	2	St. Botolph's Church
3	Hospital NHS	3	Nomura House
4	Developers	4	Milton House
5	Property Speculators	5	Postman's Park
6	Investment Banks	6	Bank of America
		7	Barts New Building
		8	Barts Old Building

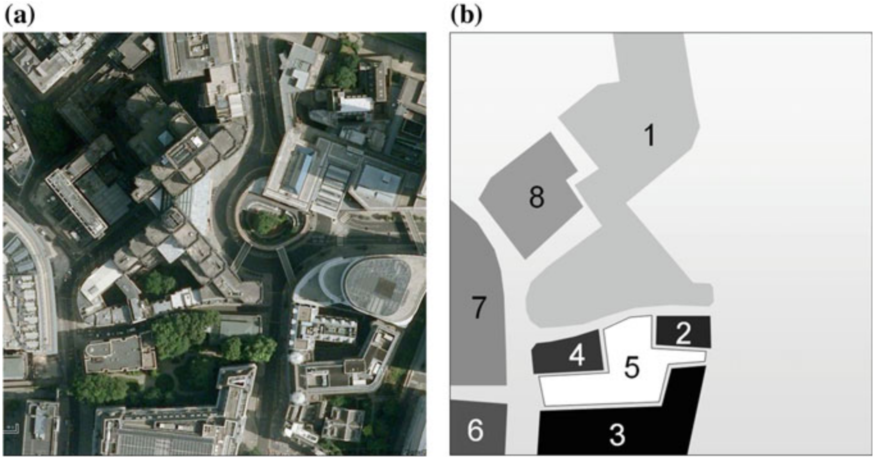

Fig. 2.1 The building complex. **a** The physical form. **b** The sites/land parcels

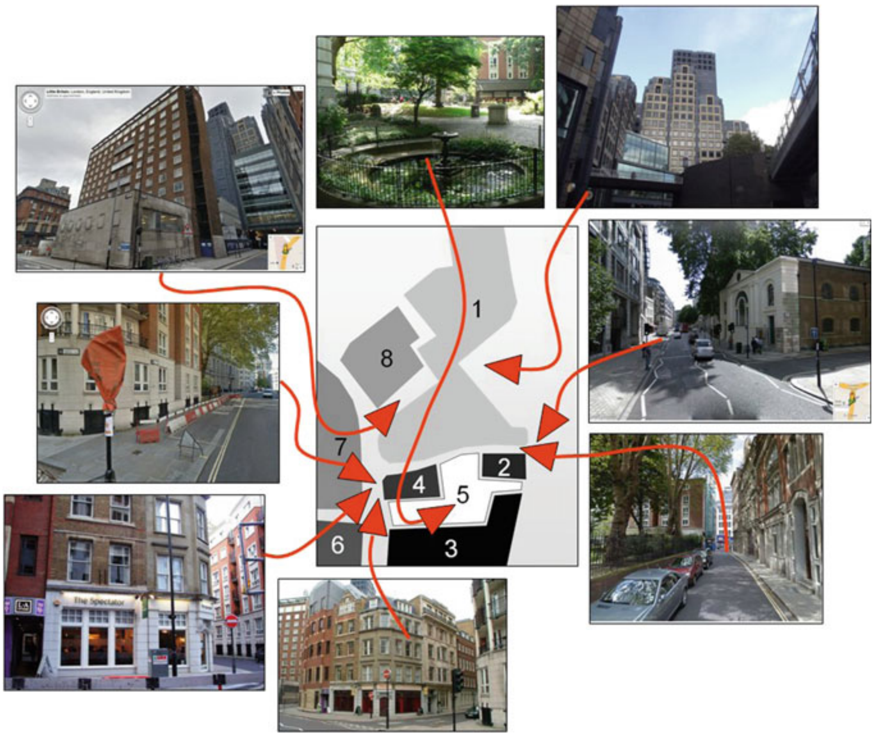

Fig. 2.2 The problem context: The Little Britain—St. Bartholomew's Hospital Site

by Nomura Bank. On the east of the Park is site 2, St. Botolph's Georgian Church, while the street that bounds the Aldersgate Complex running along Postman's Park is Little Britain, the place of John Wesley's conversion in 1738 which established Methodism a year later. At the western end of this street is site 4, residential apartments called Milton House built around the same time as the Aldersgate complex in the early 1990s. King Edward Street divides these buildings in the north-south direction with site 7, the St. Bartholomew's Hospital Old Building on its north (currently being redeveloped as apartments), site 8, the new St. Bartholomew's Hospital building south of the Old Building on the east, and south of this, site 6, the old Post Office Extension. This is now owned by Bank of America (acquired Merrill Lynch in the financial crash in 2009) who in turn had bought it from the Post Office in 2004.

This area does not have any particular symbolic imagery as it is of mixed use and much influenced by the eastward expansion of the city from the Bank of England area to St. Paul's due to the change in the location of the London Stock Exchange which is just south of the Bank of America on High Holborn. As Fig. 2.2 reveals, the area is quite attractive, particularly the complex of buildings around Postman's Park which is a classic New York City style pocket park. What is clear is that the area is subject to continual pressures relating to the fact that financial services now dominate the city and this is an area that is subject to the volatility of the financial economy, continual acquisitions and mergers that define these firms, and the extreme competition for office space that dominates different areas of the city and its extension westwards towards Bloomsbury and eastwards into the London Docklands.

We have defined 6 agents or actors who are the key stakeholders with both interest and control over the various sites. In fact we could define many more than 6 for each of the groups we identify could be broken down into different types but we need to keep the 'toy' problem manageable to illustrate the method. The first group is the City Corporation which is the arbiter of all that happens in the square mile. It controls most of the land which it owns and is leased to the many businesses and residents who make up the economic and social activity in the city. In fact its main control is over development and it tends to operate a pro-business policy but at the same time exercising considerable control over the type and visual appearance of development. The next group 2 are Residents who currently live in the complex centred on site 4 Milton House and the northern side of Little Britain which is attached to the Aldersgate Complex. This group is not particularly well-organised but as there is more apartment building planned for the area and as the streets are being reconfigured for cyclists, the residents' group is potentially a greater power broker than it has been so far. The third group is the St. Bartholomew's Hospital run by the National Health Service (NHS) who are a powerful public agency but who tend not to be interested in property except insofar as they have been selling off parts of the old Hospital buildings to private developers for apartments. The massive redevelopment of their own buildings which is almost complete now has been financed by external public finance initiatives. Group 4 are Developers who have a predatory interest in all buildings except those that they know they can never control such as churches, parks etc. The fifth group are the Property Speculators.

These are not the same as Developers as they tend not to be interested in the eventual usage or building form except insofar as they are interested in capital and finance. Last but not least there are the Investment Banks who have more ad hoc interests in property insofar as they are concerned with their international profile and nearness to other financial institutions.

We will define four different variants of the group decision problem beginning with the last that we specified, the French-Harary model. Here interest and control are not specified separately and the interactions between agents in the primal problem and map sites in the dual problem are determined as in (2.15) and (2.16). We then use the map matrix for both interest and control in the standard problem which is based on Coleman's model as we specified in (2.11) and (2.12) and this constitutes what we called the 'baseline' model that we can use to compare with any other. We then move to two variants of the full model where interest and control are specified quite separately. The first is where we simply assign random values to the **X** and **C** matrices and the second (and last) one is based on a full specification of what we regard as appropriate interest and control matrices that differ in plausible ways from one another. We can then make comparisons between the four different applications in terms of their equilibrium resource and value vectors and draw conclusions as to the sensitivity of the model, and the size of actual applications that are needed to implement this way of thinking in contrast to our 'toy' application. We then speculate on ways in which the model might be taken further to explore how planning problems of this type do not lead to consensus or solution, which some would argue is the recurrent condition in such contexts.

As a starting point we will define the map matrix which we use to define aggregate interactions and also use in the baseline model. We can write this matrix as

$$\mathbf{M}(0) = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}, \tag{2.20}$$

where Fig. 2.3 annotates this with respect to the agents and the sites. It is worth going through the elements of this matrix to focus on the rationale for associating an agent with a site for this is the essence of both their interest and control. To an extent, we might think of this as simply the interest that the agent has in change of use for the site which determines the agent interactions while the dual is simply the overall common interest that all agents have with respect to any two sites. Starting with the City Corporation, it has a strong interest in the two banks which have changed use frequently during the boom which preceded the financial crisis and its aftermath and although Bank of America now looks stable, Nomura are seeking new tenants. The Corporation also have an interest in the Barts Old Building, the new apartment complex as do the Residents whose interest is in the enhancement of the residential quality of the area. When we say that an agent or group has no

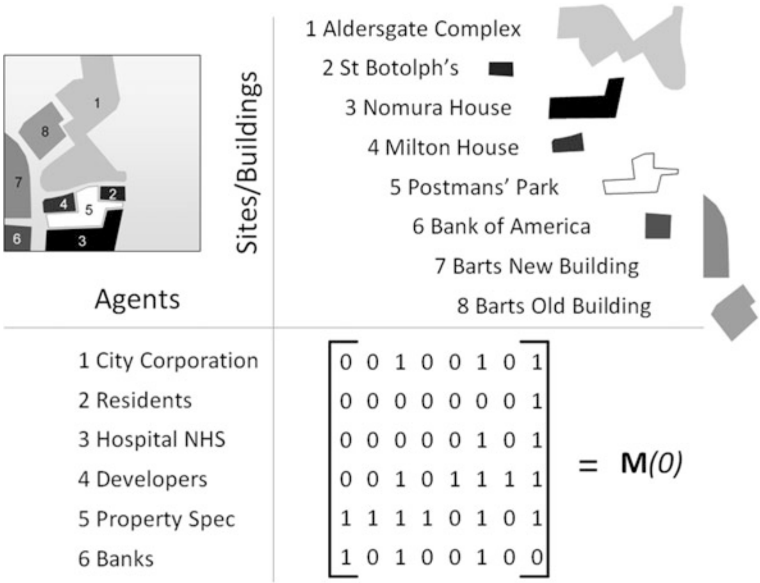

Fig. 2.3 The n × m map matrix based on relating agents to sites and buildings

interest, this is as much likely to mean that the agent has an interest in keeping a site in the same use and in this sense, all the agents apart from Developers and Property Speculators have a strong conservative outlook on what happens in this area.

The Hospital NHS Trust (St. Bartholomew's) is a state-of-the-art cancer hospital with a very old foundation which has recently been extensively redeveloped, hence the selling off of its Old Building for residential development. They have little interest in anything other than adjacent buildings but in this sense, do have a mild interest in Bank of America. Were the funds to be available for purchase of surrounding buildings, the NHS Trust would probably have a stronger interest but it is unlikely that this would ever be possible for the organisation of the hospital is based on much wider considerations that pertain to the Trust that runs it, and the somewhat parlous state of the NHS in Britain. Developers are much more predatory and have an interest in everything in the area with the exception of the residential development, the church and the Aldersgate Complex which are all protected or unlikely to be changed in any form in the immediate future. Arguably the Park is protected and unlikely to change but it could be developed more actively. Property Speculators have the widest interest but with little interest in Postman's Park or the Barts New Building. There is a mild interest in the church but only for its use value. Finally the Banks have an interest in their own use of their two sites as well as in the Aldersgate Complex which is still has space for let and which contains several financial companies that service banks in the wider city.

2.5.1 Solutions and Comparisons

Our first model is now very easy to construct as we form $\hat{\mathbf{P}}$ by multiplying $\mathbf{M}(0)$ by its transpose $\mathbf{M}^T(0)$ and its dual $\hat{\mathbf{Q}}$ by multiplying the transpose $\mathbf{M}^T(0)$ by the basic map matrix $\mathbf{M}^T(0)$. We can write these out explicitly as

$$\left.\begin{aligned}
\hat{\mathbf{P}} &= \begin{bmatrix} 312332 \\ 111110 \\ 212221 \\ 312532 \\ 312363 \\ 201233 \end{bmatrix} = \begin{bmatrix} 00100101 \\ 00000001 \\ 00000101 \\ 00101111 \\ 11110101 \\ 10100100 \end{bmatrix} \begin{bmatrix} 000011 \\ 000010 \\ 100111 \\ 000010 \\ 000100 \\ 101111 \\ 000100 \\ 111110 \end{bmatrix} = \mathbf{M}(0)\mathbf{M}^T(0) \\
\hat{\mathbf{Q}} &= \begin{bmatrix} 21210201 \\ 11110101 \\ 21411413 \\ 11110101 \\ 00101111 \\ 21411514 \\ 00101111 \\ 11311415 \end{bmatrix} = \begin{bmatrix} 000011 \\ 000010 \\ 100111 \\ 000010 \\ 000100 \\ 101111 \\ 000100 \\ 111110 \end{bmatrix} \begin{bmatrix} 00100101 \\ 00000001 \\ 00000101 \\ 00101111 \\ 11110101 \\ 10100100 \end{bmatrix} = \mathbf{M}^T(0)\mathbf{M}(0)
\end{aligned}\right\}. \tag{2.21}$$

We form the probability matrices in the usual fashion as $\mathbf{P}$ and $\mathbf{Q}$ and we can picture the stochastic interactions in these two social networks as in Fig. 2.4. Note that we will do this for each of the models in this section but our graph program does not produce directional interactions and thus what we see is the maximum interaction between agents and between sites. In fact in this first model, the ultimate steady state weights can be read off directly from the interaction matrices $\hat{\mathbf{P}}$ and $\hat{\mathbf{Q}}$. Equations (2.18) and (2.19) above can be written explicitly as

$$\left.\begin{aligned}
r_i &\propto \sum_k \hat{P}_{ik} = \sum_j M_{ij} M_{jk} \\
v_j &\propto \sum_\ell \hat{Q}_{j\ell} = \sum_k M_{jk} M_{k\ell}
\end{aligned}\right\}, \tag{2.22}$$

which from (2.21) can be written out directly as

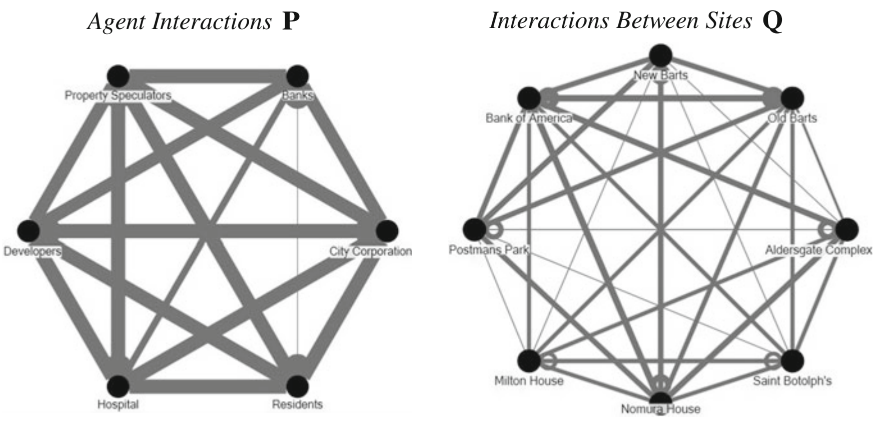

Fig. 2.4 The French-Harary interaction networks

$$\left.\begin{array}{l} \mathbf{r} = [14 \quad 5 \quad 10 \quad 16 \quad 18 \quad 11] \\ \mathbf{v} = [9 \quad 6 \quad 17 \quad 6 \quad 5 \quad 19 \quad 5 \quad 17] \end{array}\right\}. \tag{2.23}$$

The French-Harary model is in fact another kind of baseline, and we show these values in (2.23) scaled to sum to 100 in Table 2.2, where, henceforth, for the three other variants of the model we will use the same scaling. What this implies for the

Table 2.2 The steady state weighting vectors for the four models

Models	1	2	3	4	Differences		
Agents	French-Harary	Coleman Baseline	Coleman Random	Coleman Real	(2)–(1)	(2)–(3)	(2)–(4)
1	19 (3)	15 (3=)	16 (5)	34 (1)	−4	−1	−19
2	7 (6)	5 (6)	18 (1)	12 (5)	−2	−13	−7
3	13 (5)	10 (5)	15 (6)	9 (6)	−3	−5	1
4	22 (2)	25 (2)	17 (2=)	15 (2=)	3	8	10
5	24 (1)	30 (1)	17 (2=)	15 (2=)	6	13	15
6	15 (4)	15 (3=)	17 (2=)	15 (2=)	0	−2	0
Sites							
1	11 (4)	10 (4)	11 (6=)	16 (4=)	−1	−1	−6
2	7 (5=)	5 (5=)	13 (4)	3 (8)	−2	−8	2
3	20 (2=)	20 (3)	14 (3)	16 (4=)	0	6	4
4	7 (5=)	5 (5=)	9 (8)	5 (7)	−2	−4	0
5	6 (7=)	5 (5=)	15 (1=)	17 (3)	−1	−10	−12
6	23 (1)	25 (1=)	11 (6=)	19 (1)	2	14	6
7	6 (7=)	5 (5=)	12 (5)	6 (6)	−1	−7	−1
8	20 (2=)	25 (1=)	15 (1=)	18 (2)	5	10	7

The weights sum to 100 and can thus be interpreted as percentages; the numbers in brackets are their rank agents is that the most influential (for these values pertain to their weight in any ultimate consensus) are the Developers and the Speculators. The Residents have very little influence while the City Corporation is almost as powerful as the land and property interests, and although the Corporation wields great power, it is a little less interested in the sites in this area than Developers and Speculators. This makes good sense. The NHS in fact has modest power but only in relation to its adjacent sites. When we examine the sites, the most important are the banks—Nomura and the Bank of America with the new redevelopment site of Barts Old Building also having some significance. The existing residential sites, the church and the park are less important as these are shielded from an interest in further development.

Our second model uses the same data as the first but this time we have articulated it using specific interest and control as defined from the maps in (2.11) and (2.12). This is the simplification of Coleman's model where the final equilibrium vectors are simply the sum of the rows and columns of the map matrix, that is $\mathbf{v} \propto \mathbf{1M}(0)$ and $\mathbf{r} \propto \mathbf{1M}^T(0)$ which we can write out explicitly as

$$\left.\begin{array}{l} \mathbf{r} = [3 \quad 1 \quad 2 \quad 5 \quad 6 \quad 3] \\ \mathbf{v} = [2 \quad 1 \quad 4 \quad 1 \quad 1 \quad 5 \quad 1 \quad 5] \end{array}\right\}. \tag{2.24}$$

In fact these values in (2.24) are quite similar but much less sharpened versions of those generated by the French-Harary model in (2.23). This is clear from Table 2.2 where we scale them to sum to 100 and also use (2.24) as the baseline to make comparisons for all the other three models that we test. The only significant difference from the previous model is that the Barts Old Building is of top importance while the city corporation is of equal importance to the banks. It is not worth speculating on these differences for it is clear that this kind of analysis only comes into its own when the problem is scaled up with many more agents and sites and this is for future applications.

Our third model is yet another kind of baseline where we simply set each element of interest and control to random values, that is $X_{ij} \sim random(1)$ and $C_{jk} \sim random(1)$ where these values are then scaled to sum to 1 so that the two matrices are stochastic. We show the equilibrium values for a run of this model in Table 2.2 where the predictions of resources $\mathbf{r}$ and value $\mathbf{v}$ are truly random and have no meaning in terms of our set of agents and sites. Our fourth and last model is where we define interest and control in much more realistic ways. For example, the Residents may have a lot of interest in Postman's Park but no real control over doing anything about their interest. In fact this is not quite the case for as residents they can petition their local aldermen to act on their behalf but in general it is those who own sites and those who have capital to acquire them and change their use that have greater control. We have defined two matrices of interest and control that differ in these terms. The City Corporation have interest in the use of the larger buildings but no interest in the residential apartments or church or new hospital buildings because these are not going to change in the future. The Residents have an interest in the other residential building and planned apartments and the park while the hospital trust simply has an interest in its own buildings.

The Developers and Speculators have pretty similar interests in the usage of the larger buildings and banks while the Banks themselves have an interest in the buildings they themselves own. In terms of control, the Corporation has pretty much control over the entire area while the residents and the Hospital Trust's control matches their interest. Developers and Speculators control the large buildings and the banks are controlled by those who own them. The correlation between interest and control is low but positive with the percent of variance explained between **X** and $\mathbf{C}^T$ as 35 and thus there is a sufficient measure of difference between interest and control to ensure that some compromise is required.

In terms of the equilibrium distribution of resources and value, then it is the City Corporation that is by far the most powerful with the Developers, Speculators and Banks having a more or less equal control of resources. The sites that are most valuable are the largest bank buildings but the new apartments and the Aldersgate Complex are also highly valued in terms of change of use. The park is highly valued but the church is not because there is no likelihood of it being developed. The configurations of resources and values are given in Table 2.2 where it is clear that there are substantial differences between these measures and the baseline and where the biggest office building sites are the most valued. The real strength of this model is of course in sensitivity testing—to pose the question 'how can the resources of a particular agent be increased or the value of a site increased by manipulating the networks of interest and control?' And 'how easy or difficult this would be to accomplish?'

To conclude this analysis, it is worth exploring a little further the data in terms of the social networks that are implied by this application. We have already shown the

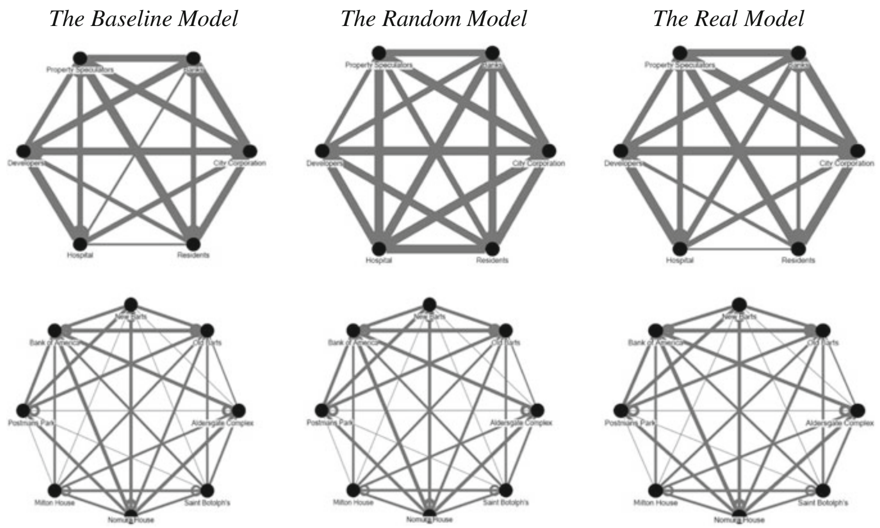

Fig. 2.5 The three variants of Coleman's model

network associated with the French-Harary model in Fig. 2.1 but in terms of Coleman's model, we will show the primal and dual networks for **P** and for **Q** for each of the three problems – the baseline where the map matrix determines both interest and control from $\mathbf{M}(0)$ associated with model 2 in Table 2.2, the **X** and **C** random matrices associated with $\mathbf{P} = \mathbf{XC}$ and $\mathbf{Q} = \mathbf{CX}$ in model 3, and the realistic matrices of interest and control associated with model 4. We show these networks in Fig. 2.5, where the key differences between interactions between agents and between sites are clearly illustrated by the amounts of interaction associated with the primal and dual probability matrices.

2.6 Conclusions and Next Steps

The models introduced here are all variants of an averaging process that assumes that networks of agents and their interest and control over development/building sites are sufficiently connected to ensure that their communication with respect to resolving differences between themselves is functional. Moreover we have assumed that rational compromise takes place, but in reality we know that this is invariably not the case. In fact, it is quite likely that in many problems of this kind, networks are not strongly connected and agents do not communicate leading to all kinds of log-jams and conflicts that often can only be resolved at a much higher level. In this sense, conflict resolution may ultimately take place but outside of the limits of the kind of problem posed here. The City of London it is likely that conflict would be resolved because the City Corporation is so powerful that it can bring massive resources in that it is the prime land owner in all development transactions.

It is quite easy to modify the model to illustrate how conflict can be resolved in such a way that the equilibrium weightings implied by these variants are distorted or modified by additional factors. For example, it is possible to build in inexorable and constant pressures where exogenous resources are continually introduced to pressure the conflict resolution towards certain directions. As the models have a linear structure, it is possible to add additional inputs in the manner sketched by Friedkin (1998) and illustrate how different exogenous weights can influence the ultimate balance of resources and values. It is also possible to add generic trends to the outcomes in the manner introduced by Blondel et al. (2005) where flocking and following are used to converge solutions that have their own dynamic. To explore these however, we need to move to much bigger problems and to problems where observational data pertaining to the actual processes of conflict resolution is to the fore. This involves grappling with group dynamics and engaging with the long stream of work on how decisions are actually reached in empirical contexts, while at the same time ensuring that the notion of design as optimisation remains to the fore.

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Chapter 3
Self-organization and Design as a Complementary Pair

J.A. Scott Kelso, Egbert Stolk and Juval Portugali

Abstract Self-organization implies that order and regularity can come into being (emerge) spontaneously as a purely bottom-up process. Design implies the exact opposite: that order and organization come into being by virtue of a designer in a top-down manner. In this paper we treat these apparent contraries as a complementary pair, and use the notion of SIRN to show how they may coexist.

3.1 Introduction

At first blush, the title invites a contradiction: self-organization implies that order and organization can come into being (emerge) spontaneously as a bottom-up process, whereas design usually means the exact opposite, namely that order comes into being by virtue of a designer in a top-down, pre-planned manner. Neither side of the dichotomy is quite true: self-organization requires both Bottom-up and top-down processes (somehow initial conditions, parameters must be set) and design ignores bottom-up collective effects at its peril. In the spirit of “Contraria sunt complementa”—the words on the coat of arms of the great Danish physicist Niels Bohr—we aim to treat design and self-organization as a complementary pair.

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We use the notion of SIRN (Synergetic Inter-representation networks) to show how apparent contraries may coexist in practice. The notion of SIRN integrates Synergetics, which is Haken's (Haken 1983) theory of self-organization in open, nonequilibrium systems, with the notion of IRN (inter-representation networks) as introduced by Portugali (1996). The scientific basis for complementary pairs comes from Coordination Dynamics (Kelso 1995; 2009) itself grounded in theories of self-organization in physics, chemistry and biology but tailored specifically to the functions of animate, living things (moving, perceiving, feeling, thinking, deciding, learning, remembering, etc.) on multiple levels of description (neural, behavioral, cognitive, social, etc.). The paper starts with a section on Synergetics, IRN and the HKB model (Sect. 3.2). Section 3.3 is about complementary pairs and their scientific underpinnings which lie in *metastable* coordination dynamics. In Sect. 3.4 self-organization ~ design is described as a complementary pair. The paper concludes with some remarks on future research (Sect. 3.5).

3.2 Synergetics, IRN and the HKB Model

Synergetics—the science of structure—focuses on how the many microscopic parts of a complex system work together to produce structure and pattern at a macroscopic scale. As such it is one of the founding theories of complex systems (Haken 1983). Since its early beginnings in laser theory in physics, synergetics has embraced a wide spectrum of domains ranging from chemical clocks, biological pattern formation, the economy, cognition, brain function and even the sociology of science itself (Haken, 1984)—as well as society and of course cities (Portugali 2011).

As a means of understanding, the concepts and methods of synergetics were developed in the context of specific phenomena that became its basic paradigms: the laser paradigm, the fluid dynamic paradigm, the pattern recognition paradigm, and the finger-movement paradigm. The scenario common to all the various cases may be described as follows: A given internal or external control parameter that is acting on the system promotes or enhances interaction between the system's many parts. The resulting motion may be interpreted as a consequence of several systemic partially ordered states competing among themselves. When the control parameter crosses a certain threshold, the hitherto rather chaotic form of motion suddenly and spontaneously gives rise to a coherent movement and interaction where all the parts behave in concert. This coherent movement, which can be precisely quantified, is called an *order parameter*. The process by which the many parts abruptly "obey" the order parameter and in this way support and reproduce it is called the *slaving principle*. This is illustrated in Fig. 3.1. In Haken's (1984) words (for the case of the laser):

> Because the order parameter forces the individual electrons to vibrate exactly in phase, thus imprinting their actions on them, we speak of their "enslavement" by the order parameter. Conversely, these very electrons generate the light wave, i.e. the order parameter, by their uniform vibration.

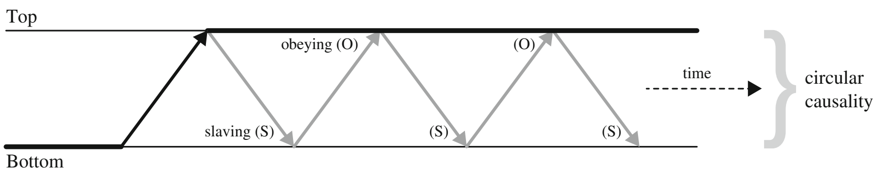

Fig. 3.1 The local interaction/synergy between parts (*bottom*) gives rise to an order parameter (*top*) that then enslaves the behavior of the parts (*bottom*). By 'obeying', the parts strengthen and reproduce the order parameter and so on in a so-called circularly causal fashion

It is easy to imagine how one may substitute other kinds of parts (e.g. neurons, muscles, molecular species, individuals producing a wave, etc.) in other kinds of system (brains, chemical reactions, social settings, etc.) for the same circularly causal principle to be applied.

3.2.1 Inter-representation Networks

IRN (inter-representation network), the second component of SIRN, started from the observation that many cognitive processes that cannot be executed by a single cognitive act are implemented by a sequential interaction between internal representations constructed in the minds/brains of people and external representations constructed by them in the world in the form of utterances, texts, drawn figures and the like (Portugali 1996).

In developing SIRN, Haken and Portugali (1996) formulated a general SIRN model that is illustrated in Fig. 3.2 (right). This general SIRN model can be seen as symbolizing a complex self-organizing active agent—say, a designer—that is

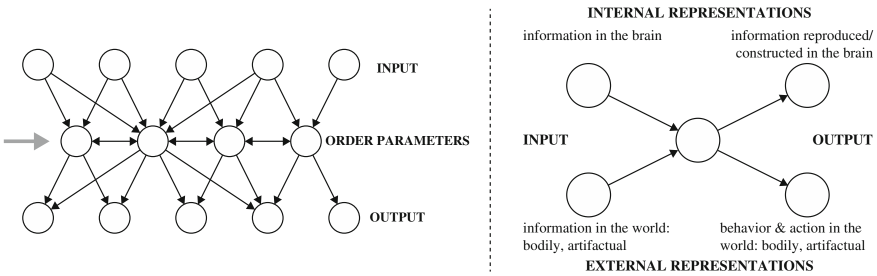

Fig. 3.2 *Left* Haken's synergetic computer. *Right* The basic SIRN model as derived from the synergetic computer. SIRN symbolizes a self-organizing agent that on the one hand is subject to two forms of information (internal and external) and on the other actively constructs two forms of information, again internal and external. It is obvious that the SIRN model is a transformation of the synergetic computer: to appreciate this, view the latter from the side (*grey arrow*), make the distinction between internal and external representations and rotate it 90° counterclockwise

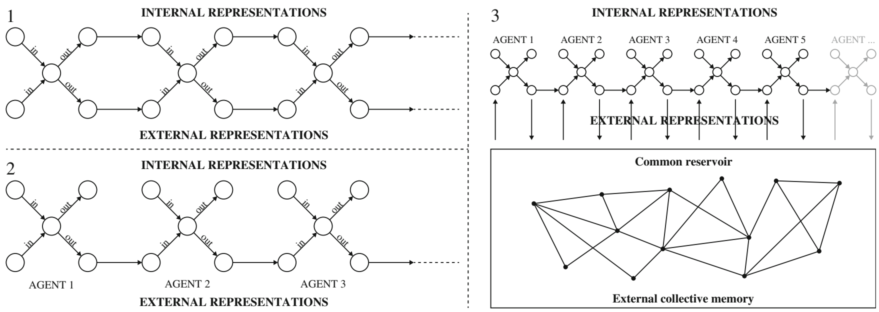

Fig. 3.3 Three SIRN sub-models. *1* the intrapersonal model; *2* the interpersonal-sequential model; and *3* the interpersonal-collective model

subject to two flows of information: internal and external. The first is coming from the mind/brain, in the form of ideas, fantasies, dreams, thoughts, imagination, emotions and the like, while the second comes from the 'world' via the senses, the agent's body and/or artifacts. The interaction between these flows gives rise to an order parameter that governs the agent's action and behavior, as well as the feedback information flow to the agent's mind. In an analogous fashion, the 'feedback information flow' refers to the formation of internal representations, such as images or learned patterns. The order parameters are determined by a competition along the lines of synergetic pattern recognition.

In order to apply the general SIRN model to specific case studies, Haken and Portugali (1996) derived three prototypical sub-models that refer to three principal cognitive contexts: the *intrapersonal*, the *interpersonal-sequential*, and the *interpersonal collective,* as shown in Fig. 3.3. The first refers to a solitary agent, the second to the sequential dynamics of several agents, and the third to the simultaneous interaction among many agents.

3.2.2 *The Classical HKB Model of Coordination Dynamics: Multistability and Phase Transitions*

The most primitive form of self-organization in nature's open systems is the non-equilibrium phase transition (Haken 1983). Near instabilities where patterns form and change, certain features are predicted such as critical slowing down (when the system is perturbed it takes longer and longer to restore the value of the order parameter) and fluctuation enhancement (the variability of the system's state increases dramatically as a critical point approaches). Can such signatures of self-organization be found in complex, biological systems? This is important because—consistent with the present theme—the observed order and regularity in living systems is often attributed to a designer-like 'plan' or 'program' (usually located inside the system) that is said to be responsible for the order and regularity

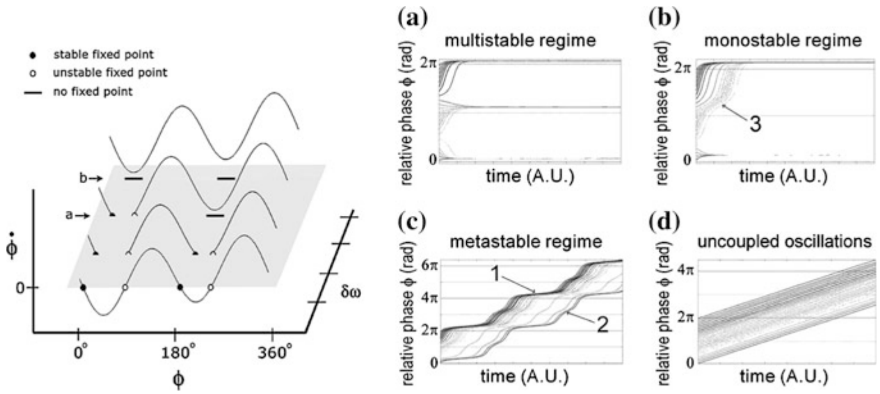

Fig. 3.4 Multi- and metastable coordination dynamics: *Left* The broken symmetry version of the HKB model [12]. δω represents the heterogeneity of the individual coordinating elements. At low values of δω there are two stable fixed points (*solid circles*), resulting in a bi-stable regime. At (*a*) due to changes in control parameters one of the two fixed points disappears and the system switches spontaneously from being bi-stable to being monostable. At (*b*) a saddle node or tangent bifurcation occurs and all fixed points disappear, yet remnants or ghosts of the attracting and repelling fixed points remain. This is the metastable regime. *Right* The four different types of dynamical trajectories. Note the dwell ~ release dynamics characteristic of metastability where the trajectories pause near places where the stable fixed points used to be. Image source (Engstrøm and Kelso 2008, Figs. 1 and 2)

observed. The Haken-Kelso-Bunz (HKB) model (Haken et al. 1985) and its stochastic, Fokker-Planck version (Schoner, Haken & Kelso 1986) were formulated to account for the discovery of nonequilibrium phase transitions in human bimanual coordination (Kelso 1984) (the so-called finger movement paradigm referred to earlier)—a clear demonstration of self-organized behavior in an individual person. Phase transitions and associated phenomena were also found in experiments in which individuals had to coordinate their body with external stimuli (Kelso et al. 1990) and even between two people when they spontaneously coordinated with each other (Schmidt et al. 1990). The HKB model uses concepts of synergetics (order parameters/collective variables, control parameters, instability, etc.) and the mathematical methods and tools of nonlinearly coupled dynamical systems (attractors, bifurcations, fluctuation measures, relaxation times, etc.) to account for self-organized behavior at both cooperative, coordinative levels and at the level of the individual coordinating elements. The system's dynamics may exist in monostable or multistable regimes (see Fig. 3.4 right, a and b) (Kelso 2008). Engstrøm and Kelso (2008) describe the essence of multistability as follows:

> In the case of multistability, which attractor is reached in the multistable regime primarily depends on initial conditions. Once the system has settled into an attractor, a certain amount of noise or a perturbation is required to achieve a switching to another attractor. If control parameters such as attention or frequency are modified, a bifurcation or phase transition from multistable to monostable states and vice versa may occur.

3.2.3 *The Extended Version of the HKB Model: Metastability*

In complex systems, component parts and processes are seldom identical–structurally or functionally. If left to its own devices, each participating element will tend to display its own intrinsic behavior. Such heterogeneity breaks the (spatiotemporal) symmetry of the HKB model and changes its entire dynamics (Kelso 1995; Kelso et al. 1990). One truly novel outcome is that the combination of coupling and symmetry breaking (represented in extended HKB as $\delta\omega$, cf. Fig. 3.4) can give rise to *metastability*. In the metastable regime all the fixed points, whether stable or unstable, have vanished. Yet the formerly stable fixed points act as magnets or *tendencies* or *dispositions* that can be quantified by the distribution of their *dwell* times and *escape* times. Engstrøm and Kelso (2008) describe the essence of metastability as follows:

> …in the metastable regime of coordination dynamics, successive visits to remnants of the fixed points are intrinsic to the time course of the system, and do not require any external source of input (Kelso 1995). This is an important difference between multistability and metastability, and likely translates into palpable differences in fidelity of performance, as a system in its metastable regime isn't hindered by fixed point behavior, while a multistable regime is. An important point—especially for those who study multistable phenomena—is that the extended HKB model of coordination dynamics captures both multistability and metastability.

Although Kelso and colleagues focus on brain dynamics in their research on the *metastable brain* (Kelso 2001, 2012; Tognoli & Kelso 2014), metastability is not viewed as limited to the level of human brain and behavior, but is proposed to be an essential property of all complex systems (Kelso 1995; 2009).

3.3 Complementary Pairs

Kelso and Engstrøm describe a "philosophy of complementary pairs" in their book *The Complementary Nature* (Kelso and Engstrøm 2006). Complementary pairs are those things, events and processes in nature that may appear to be contraries, due in part to our ubiquitous tendency to dichotomize, but are mutually related and inextricably connected. Kelso and Engstrøm introduce the tilde or squiggle ($\sim$) to indicate the complementary nature of a complementary pair, to emphasize the *dynamical* and *relational* nature of the two aspects of a complementary pair. These apparently polarized entities are referred to as *complementary aspects* (ca1 and ca2 in Fig. 3.5). For example, body and mind are complementary aspects of the complementary pair body $\sim$ mind. The general idea is that contraries are complementary, not contradictory (though one should be careful with language; complementary and contradictory may themselves be viewed as a complementary pair!). Importantly, it is not only the polar complementary aspects of complementary pairs that matter, but also all the stuff and all the action falling in between

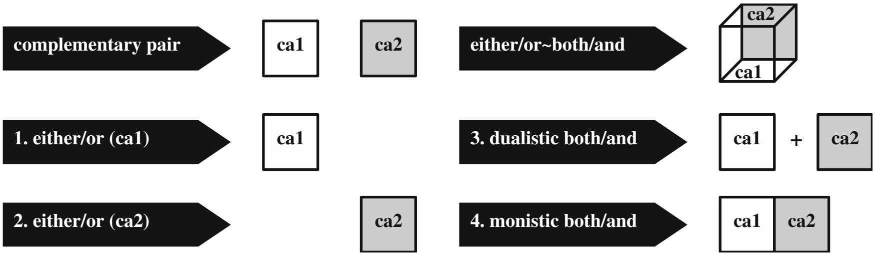

Fig. 3.5 Kelso and Engstrøm's illustration of four basic interpretations of complementary pair *ca1 ~ ca2* and their reconciliation. Image source (Kelso and Engstrøm 2006, Fig. 1)

them. In Fig. 3.5 four basic interpretations of a complementary pair ca1 ~ ca2 are given. The Necker-cube represents the inextricable relation between the complementary aspects.

The scientific basis of complementary pairs stems from metastable coordination dynamics: "in coordination dynamics, where apartness and togetherness coexist as a complementary pair—where a whole is a part and a part is a whole—there are no equilibria, no fixed points at all." (Kelso and Engstrøm 2006, p. xiv). Multistability ~ metastability and states ~ tendencies are considered key complementary pairs of coordination dynamics. Engstrøm and Kelso conclude: "to gain more understanding of the mechanisms of metastability, it seems necessary to invent new strategies that study metastable coordination patterns in different fields, systems and levels, and to establish criteria for the differentiation of state transitions and patterns of converging ~ diverging dwell ~ escape behaviors" (Engstrøm and Kelso 2008).

3.4 Self-organization~Design

3.4.1 Design Thinking

Design Thinking, or Design Cognition, is a domain of research that studies the general process of design as it is implemented in various domains ranging from engineering to architecture, crafts, arts and more. Stolk and Portugali (2012), Portugali and Stolk (2014) suggest that designing is a *cognitively complex activity*. Such an activity starts with a vague idea in mind that is externalized by sketching/drawing, followed by interplay between several internal and external representations.

In the practical process of design, designers need to constrain the so-called *design-space*. For this purpose they often impose a (top-down) *primary generator* or use bottom-up opportunistic design strategies or combinations of both. By doing so designers explore the 'design territory' in which the design problem and solution co-evolve (Dorst and Cross 2001). (Note problem ~ solution are a complementary pair).

The design medium, as an active participant in the design process, is highly relevant for the outcome. Sketching, for example, is known for its ambiguous nature, offering emergent properties that were not intentionally put there (Tversky and Suwa 2009). Computer models are known to lead to fixation in the design process, but can be useful to complement the limitations of our mind ~ brain (Mallgrave 2010). Internally, associative memories, precedent knowledge and design expertise can play a crucial role. Reading between the lines, the domain of Design Thinking shares a lot of properties with SIRN (Portugali and Stolk 2012).

The focus of the domain of Design Thinking was always the individual designer and small-scale objects (relative to the human body). Recently, however, we see a growing interest in collective design and the entire context surrounding the design situation. What is still lacking is a focus on the design of large-scale objects such as cities.

3.4.2 SIRN Design: Three Forms of Design Processes

Derived from the general SIRN model the above noted SIRN sub-models suggest to Design Thinking three forms of design that correspond to the three aspects through which design may be said to be complex (Portugali and Stolk 2014): the *intrapersonal SIRN design process* implemented as it is by a single designer corresponds to the fact that the designer is a complex system; the *interpersonal-sequential SIRN design model* that is specifically appropriate to model the space-time evolution and/or diffusion of design forms and styles corresponds to the property that the design situation is a complex system; and finally the *interpersonal-simultaneous SIRN design process* that is implemented as a group dynamics by several designers working together (but also by a single urban designer), corresponds to the finding that in the case of cities and urban design, the designed object—for instance the city—is itself a complex system.

3.4.3 Self-organization~Design at Three Complementary Levels

From The Complementary Nature we learn to look at a (seemingly) contrary pair as consisting of two complementary aspects of a single complementary pair—in our case the *self-organization aspect* and the *design aspect* of the self-organization ~ design pair. From SIRN we learn to describe the urban design process on three interrelated levels. These relate to two complementary pairs: intrapersonal ~ interpersonal and sequential ~ simultaneous—which link the three sub-models as shown in Fig. 3.6.

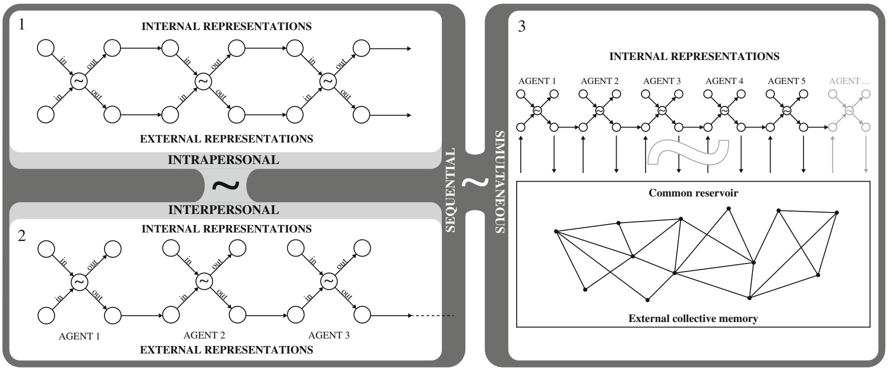

Fig. 3.6 The three SIRN sub-models as a related metastable ~ multistable system (see text for discussion)

Describing *self-organization ~ design* as a complementary pair within the context of the three SIRN sub-models offers a new understanding of the designer and its context. Firstly, the design process consists of the complementary pair *internal ~ external representation*, as briefly described in Sect. 3.4.1. Here we find some other complementary pairs. *Ambiguity ~ clarity* refers to the different types of representation used in design. The concept of fixation is part of the *fixation ~ flowing* pair–where the concept of 'flow' implies a metastable state of mind, guided by tendencies, while the concept of 'fixation' implies a mono/multistable state of mind, fixed by states. Another distinction is made between analysis and synthesis, describing them as different, time-bound phases as commonly used in Design Thinking literature (Braha and Maimon 1997). *Analysis ~ synthesis* suggests that designers actually apply both at the same time, as noticed by some experienced practicing designers/architects (Kleijer 2004). Secondly, the *intrapersonal ~ interpersonal* pair gives an idea about the *designer ~ design* situation. And thirdly, in the case of urban design, it gives a hint about the coordination dynamics of *individual ~ group* designer(s) and the *human ~ environment* or more specifically *urban designer ~ city.*

3.5 Concluding Remarks

This short paper is a first exploration of the relation between the concepts of complementary pairs, metastability, synergetic inter-representation networks and (urban) design. The contradiction of top-down design and bottom up self-organization vanishes in light of the complementary pairs and SIRN: bottom-up and top-down are complementary, not contradictory. This view needs to be and will be extended and elaborated in more depth, to come up with a more comprehensive view on the three SIRN levels of urban design. Nevertheless, it can be concluded that such a perspective has the potential to shed new light on the process of (urban) design—a design field without, as yet, a strong tradition of explicit theorizing from a self-organizing ~ design-thinking point of view. At the same time, urban designers have developed ways of dealing with complex systems in a more implicit way, which can inspire scientists to come up with useful insights on the dynamic nature of urban design. If designers will learn to exploit their multistable ~ metastable mental capabilities better, by not sticking to contraries as contradictions or polarized opposites, they might face the challenges of the rapid urbanization worldwide in a more effective way.[1]

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[1]Throughout the *2nd Delft International Conference on Complexity, Cognition, Urban Planning and Design*, one is struck by the relevance of complementary pairs and their (coordination) dynamics in numerous presentations and contexts. A few examples in no particular order are: Design cannot be a solitary activity (Batty: solitary ~ team, individual ~ collective). Cities create creativity; there is spatialization of the social and socialization of the spatial (Hillier, social ~ spatial, boundary ~ domain). Termite architecture; a balance of thermodynamically forward flux (TFF) and physiological flux(PF) (Turner, dispersal ~ deposition; homeostasis ~ homeodynamics; intensive ~ extensive). Rats exploring novel environments (Hediger, repeated routes ~ creating places). The brain's maps and neural networks (Haggard, cognitive ~ affective, unity ~ diversity, symbolic ~ dynamical; syntax ~ semantics). Knowledge and uncertainty (Sela, ontological ~ epistemological). Working with water, the Delta, 'in between' zones (Meyer, layered ~ rhythmic, spatial ~ temporal, past ~ future, dispersion ~ deposition, slow modes ~ fast modes). Cities as Complex (Portugali, artifactual ~ natural, potentialities ~ possibilities, simple ~ complex, parts ~ together, this contribution). The City in history, the built environment (Harbruken, simple ~ complex, unifying principles ~ diverse mechanisms; stasis ~ change; rules ~ dynamics; create ~ reproduce, variety ~ consensus, modularity(parts) ~ design (whole).

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Chapter 4
Cultivating Complexity: The Need for a Shift in Cognition

N. John Habraken

Abstract Cities and towns are the result of acts like building, renovating, maintenance and adaptation that continue over time. This makes them behave like living organisms of considerable complexity. Closer examination allows us to distinguish two kinds of complexity. Contemporary construction is about the combination of a large number of subsystems that not only enclose spaces and hold up weights but also, among other things, distribute power, water, and gas; cool, heat up and circulate air; remove waste and serve communication. Each subsystem is available in a variety of alternatives. This technical complexity has produced a professional culture that itself has become increasingly intricate and self-referential. By comparison, historic built environments were the result of much more constrained material conditions that could nevertheless produce very sophisticated solutions. Their complexity was not technical but the result of continuous small scale change over time in direct response to inhabitation. We live in a period of transition in which an entirely new material reality must learn to serve the millennia old ways of human settlement. This chapter argues that this is not a technical problem. It demands a re-examination of our professional culture.

4.1 Field Control

The apparently effortless complexity of traditional human settlement patterns has always fascinated me. Evidence of their variety is still available. We are of course familiar with the urban fabrics of Cairo, Venice, Amsterdam and many other famous cities, and the 'vernacular' fabrics of Mediterranean hill towns have attracted architects for generations. Much can be learned from studies of the extremely complex Middle Eastern historic fabrics that emerged for millennia from bottom-up control processes by social consensus. Age old ways of settlement can still be visited today like those of the Indonesian and Malayan kampongs.

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The extensive spontaneous self help urban growth around today's rapidly developing mega cities are worth serious attention exactly because they have much in common with historic processes.

Then there are old maps: those still available from historic cities in Europe, from the early settlements in North America, and the colonial cities in Latin America as well as the famous huge map of Beijing in 1748 where bays of every pavilion in every courtyard house are shown. And of course records of the excavations of Pompeii and Herculaneum as well as Classical Greek towns present detailed evidence of towns inhabited more than 2000 years ago. All these examples of human settlement suggest a one-to-one compatibility of social and material structure; a marriage that recurs across a variety of scales and patterns, as well as across millennia; showing both longevity and resilience.

All these fields of settlement—or built environments, as we now call them—have an organic quality. They follow implicit laws that nobody invented but which framed professional experience and innovation.

Contemporary built environments are so different from historic examples that Modernist ideology can be excused for thinking that comparison with them was no longer relevant. According to it, we just live in a new and fundamentally different world.

But history moves slowly and, while architectural styles change and building techniques develop, there is no reason to assume that patterns of human settlement which have persisted for millennia in spite of wars, migrations, natural disasters and very different cultural values, can suddenly be dismissed as no longer relevant.

My generation was probably the last to have personally experienced the seduction of Modernist ideology. After the second world war architects and other professionals believed sincerely that built environments could be conceived from a blank slate. I remember how, when I was a student, one of our renowned teachers, whose name I will not mention, declared with passion in an academic meeting that if we failed to design the right city for the future a third World War would be inevitable. And nobody laughed…

Over 500 years ago Leon Battista Alberti declared that a surge of 'wonderful creativity' had created a new professional—the Architect—free from ingrained habits, who could invent entirely new kinds of buildings. From the 1550s Palladio became the outstanding role model. The new professional designed villas for the rich and palaces for the nobility, the church, the town hall, the castle and other projects of public importance as products of a single creative individual. Meanwhile, the everyday environment took care of itself in the age-old way, using accepted typologies and growing according to collective values. Traditional master builders continued to operate as their fathers and grandfathers had done, adapting to new circumstances and social preferences in their own deliberate and unassuming way.

Modernity changed that happy co-existence. Industrialisation brought workers in ever larger numbers to the rapidly growing cities. New ways of building and management rendered historic examples obsolete—or so, at least, was the generally accepted opinion. For the professional reared in the tradition of innovative artistic intervention, the everyday environment was no longer a stable background that would take care of itself: it became a design problem to be solved.

This remarkable shift was virtually completed after the Second World War. It is a safe bet that at least 95 % of architecture students will spend their professional lives designing mostly, if not exclusively, for the everyday environment. This turn of the professional role never caused us to question our ability to deal with a fundamentally different task in terms of skills, knowledge and judgment. The result is a disturbingly contradictory ideology. Today, anything that can be built can be "Architecture". Yet we cling to the idea that its task is to make the special thing in defiance of precedence. How can everything be special?

In the mid sixties, my fascination with built environments, both historic and contemporary, made me ask myself what basic properties they all share. A quarter century later I published a first attempt to answer the question[1]; We need to understand what made built environments bloom and adapt to daily life for thousands of years. If we expect the medical doctor to know how the human body works before operating on it, we must equally understand how built environments live and stay healthy before we intervene in them.

In the book mentioned above I look at the built environment as the result of patterns of human control. Control of physical things is defined as the ability to change them, and control of space the ability to refuse entrance to it. Control, therefore, equals the ability to intervene, which makes the observation of change and movement the key to our study of environment.

This approach is not new. Observation of transformations is the most common way to study nature. Patterns of form behaviour reveal an inner structure. We need not know the intentions and meanings of the agents who exercises control, but we must look at what happens to the built environment as a result of their actions.

In terms of control, *inhabitation* means both the control of a space and the control of things in it. This combination of control I will call a 'control field' or just 'field'. Thus 'field control' is the kind of control exercised by the inhabitant party over its space and the things in it.

The office worker's cubicle and the personal belongings brought into it, make a control field. So do the home owner's house and garden and their content, the space in a rented apartment and the occupant's furniture and other belongings in it, as well as the public spaces and public buildings that a municipality is responsible for.

Control of space is territorial. It is about deciding who and what may enter it. Field control also includes control of material things. We do not only allow things to be brought in our space, but also determine their location within it as we combine them into larger configurations.

A control field is local by definition. As such, it constitutes environmental energy. The sum of a built environment's control fields make it 'live' and 'behave'.

[1]N.J. Habraken *The Structure of the Ordinary: Form and Control in the Built Environment*. MIT Press. 1998. Jonathan Teicher editor.

Of course other modes of control are exercised in built environments: The home owner who rents out a space for profit is not its inhabitant and does not control a field but reduces local inhabitant control of physical things to furniture and personal belongings. A *builder's control* is temporary and limited to manipulating material things within someone else's territory. He comes from outside and when the job is done leaves what he made where he made it. *Commercial control* is about buying and selling spaces or things and generally dislikes territorial boundaries as obstacles in its desire to move things to where customers are. It cannot constitute the integration of space, things and inhabitation that makes a *living field*. *Design control* is also temporary, and can be exercised on behalf of a field control party or a commercial party. In an ideal world controlling parties feed, serve, and help improve fields.

Field control causes the environmental complexity that we admire in historic built environments. In its smaller scale manifestations it represents the 'bottom up' process that is often considered desirable for environmental quality. It produces a complexity that is natural and spontaneous and, by definition, responds to inhabitant values and needs. No two individuals ever act in exactly the same way. Hence the more field control is distributed among many inhabitant parties, the greater the variation in form that results, and the more we will experience a built environment as complex. Also, the more these variations are thematically similar in their individual differences the more environmental complexity strikes us as the result of a coherent culture of inhabitation.

Historical complexity was achieved with extremely limited technical means and available materials. Yet it appears that our contemporary built environments, in spite of their undeniable technical and form making energies, are less complex than their historical counterparts. Compared to the natural and fine grained variety exhibited by the historical examples that we know about, our most advanced contemporary environments appear repetitive and uniform: a sure sign of the absence of small-scale field control. However, the environments we produce today shelter a society that prides itself on individual freedom of choice and self expression, This betrays a misalignment between our present social culture and its physical environment.

This misalignment is not universal. In most parts of the world people live and work in the age old way of the single dwelling containing one or two families, often combined with a work place or store. But in contemporary large-scale construction projects built volumes must shelter populations the size of entire neighbourhoods or small historic towns, and inhabitant initiative gives way to centralised professional control. The result is repetition of uniform windows, facades, floor plans and entire buildings. This cannot be the harbinger of a future culture. Why should small-scale field control have become so suddenly obsolete, after successfully serving human life for millennia? It is more reasonable to believe that we find ourselves in a period of transition in which we have yet to learn how to trigger fine grained patterns of field control with the managerial and technical abilities of our age, thereby producing truly complex environments that have never been seen before but nevertheless show kinship to historic examples?

4.2 Hierarchy of Control Fields

The examples of field control cited earlier suggest a hierarchical order among them. A member of a household may have a private room into which others have no unbidden access. Similarly, the room rented out to a boarder is a territory of its own included in the landlord's domain. That shared domain, in turn, is found within a larger one as well. An apartment building or a gated community or, less clearly defined, a street or neighbourhood all are fields that contain a number of dwellings as smaller control fields which are included in, and contribute to, the whole. Such collectively inhabited entities are, in turn, part of the entire municipal field. Hence the spatial order of control is one of inclusion. A territory resides in a larger one and may contain smaller ones. As for material things, the control of access that comes with a territory means that what reaches the boarder's room must first cross boundaries of larger fields. The city may refuse the boarder the right to carry a fire arm, while the landlord may forbid him to bring in cats and dogs.

The hierarchy of inclusion among control fields may differ in depth from one culture to another. To reach the front door of a suburban villa from the public street only one territorial boundary must be crossed, against two to enter a similar house in a gated community. The apartment in a high-rise building is two territorial crossings away from the street compared to one for the townhouse on that same street. Historic fields like those of Cairo and Beijing to mention only two, had gates that guarded access to entire streets and even neighbourhoods making for deep territorial hierarchies.

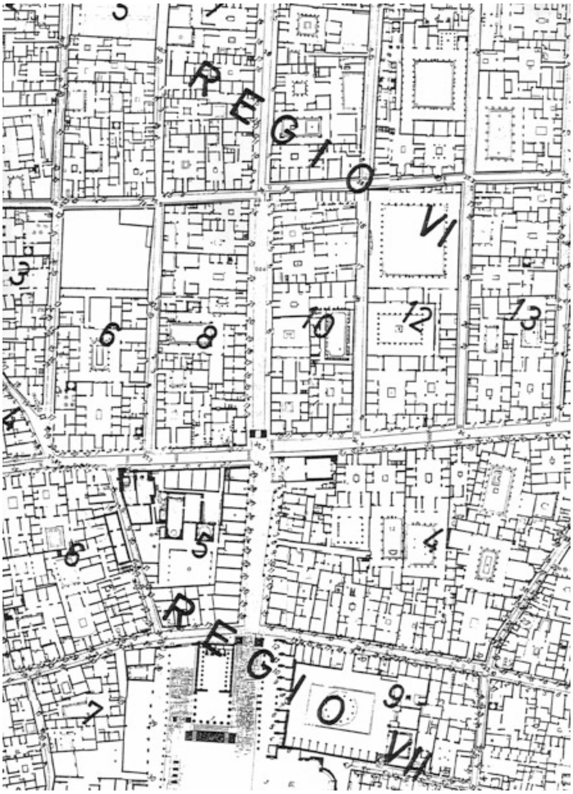
The concepts of 'public' and 'private' turn out to be relative depending on the direction in which we move. The boarder leaves his private room to enter the house's hallway, stairwell and communal living space that make a 'public' space shared with other inhabitants of the house. Those who leave the house step out into the street which is the public space of a larger field relative to which the entire house is a private space. Hence in any territory we may find included spaces that we call private and a space which is 'public' to all territories that can be reached through it. But such a 'public' space is 'private' to the larger territory in which it resides. In other words, the space we find ourselves in is considered public relative to territories it gives access to and private relative to the 'outside' space it has access to. This phenomenon is reflected in the a-symmetric function of a gate: we can close it to what comes from outside but at all times it allows us to come out into that outside space.

The territorial hierarchy puts control fields in a 'vertical' relation to one another. Neighbours visit one another by way of two vertical crossings: out into the shared public space and down again into a private space. We avoid a direct 'horizontal' crossing of boundaries: it is generally 'not done' to step into a neighbour's backyard from one's own, and consequently no gate is found in the fence between the two.

But there are 'horizontal' relations among neighbours as well. They have to do with shared values. The material configurations that we control reveal our personal preferences, needs, and means, but also the values we share with neighbours. Shared forms, types and patterns, betray horizontal relations between inhabitants operating on a same level. They make an environment coherent and we identify ourselves by the way we personally interpret them.

Venice, part of the 14th century map by Jacopo de Barbari

Tunis, part of the base map of the historic Medina. By the Association Sauvegarde de la Medina.



Pompeii, part of the map by Overbeck 1884

Amsterdam, part of 17th century extension. KLM Aerocarto

4.3 Weakness of Contemporary Fields

4.3.1 Aspects of Hierarchy

When we rent a unit in an apartment building we are in full territorial control behind the front door, but have material control only over the furniture. In a hotel room even the furniture is part of higher-level control. If furniture is all we can manipulate our level of control is weak indeed. The owner-inhabitant of an apartment unit is able to knock out partition, set up a new bathroom or change the kitchen. When we own and inhabit a villa with its own garden, our degree of material control is stronger still.

Even with a horizontal sharing of values no two control parties will act in the same way; the result will be variety from control unit to control unit. When all the doors in an apartment corridor are the same in shape and colour we know they are centrally controlled. The identity of a controlling party is not important. Central control can be collective: a board representing lower-level inhabitants can decide all front doors will have the same colour.

When field control is widely distributed, variety is the natural result and is experienced as complexity. Centralised control makes for repetition. When operating on a single level of intervention it can frame lower level variety: An office tower can have a uniform curtain wall facade and a wide variety of occupant floor plans inside.

In residential projects, high-rise and low rise, central design control often stretches over several levels with repetition and uniformity of floor plans as result.

4.3.2 The Proliferation of Technical Systems

It is often argued that contemporary construction is extremely complex and therefore needs centralised control to be successfully implemented. The complexity mentioned in such cases has nothing to do with field control. Over the past century building practice increasingly became the combination of numerous technical systems, including: different kinds of load bearing systems, facade systems incorporating a variety of environmental control techniques, diverse partitioning systems, an almost infinite choice of sanitary and kitchen equipment and, most complicating of all, a proliferation of options for service systems such as water, gas, heating, waste disposal, electric power and modes of communication. These service-systems are buried in walls, and run above hung ceilings or under raised floors. Each sub-system had its own specialised workers coming into and leaving the construction site. Choreographing all these parties increasingly taxes the abilities of managers, rule makers, designers and other professionals.

The distribution and combination of the many new material sub-systems remains a technical coordination problem, and has created ingrained specialisations the management of which, in turn, is the main excuse for centralised control. As a result, technical coordination (or rather, the lack of it) and management complexities (ever on the increase) prevent rather than stimulate true field control distribution. By definition, unsolved technical problems cause technical complexity—and thus a constraining kind of complexity. This must be distinguished from the complexity caused by distribution of field control which is a sign of freedom and opens up possibilities.

4.3.3 Invisible Territorial Control

Perhaps the most intriguing question arising from a comparison of historic and contemporary built environments is why the latter entirely lack architectural expression of gates and boundaries as means of territorial control. In the historic city the elaborate presence of gates—both functional and symbolic—was the pride of inhabitants and a major factor in defining its architecture. The present absence has nothing to do with absence of territorial control as such. The very fact that our contemporary environment is increasingly equipped with all manner of devices, electronic and mechanical—often hidden and always unassuming—to alert the fearful inhabitant is proof that today's citizen does not feel safer than his forbearers in history, yet expression of gates and boundaries is no longer part of our culture.

The modernist architectural ideology was one of total free space without boundaries. Of course, transitions from inside to outside and from light into darkness are aspects of architectural form that all schools teach, but these are mainly used to create a spatial experience rather than to express control. The means of closure and control of passage do not inspire the designer and their application is apologised for by the user as only a necessary intervention.

An explanation for this baffling observation remains to be studied but it may be relevant to note that among professionals it may come down to our own territorial instincts. We love 'public' space to be a product of our intervention in the city, and tend to reduce open space that citizens take care of themselves because it reduces the scope of professional control. We prefer unfenced front yards to increase the public realm and prefer collective backyard space in urban blocks over its subdivision in private gardens. In the US, suburban culture front yard fences are frowned upon as 'not done' and, where allowed elsewhere, are rarely considered as means of urban coherence by designers. The historic environment however, as a bottom up product, sought to minimise public space as dangerous and costly to control, and guarded its backyards by placing buildings right at the edge of public space. The result was that streets and squares were full of people and enlivened by social interaction.

4.4 Spontaneous Emergence of Field Control Hierarchy

Human nature will eventually assert its ways, adjusting new technology and managerial skills to its preferences. An increase of territorial depth can be noted in contemporary environments wherever lower-level field control asserts itself. I cite five examples of this resurgence of depth in field control at a range of scales:

4.4.1 The Two-Level Office Building

When in nineteenth-century Chicago steel structures, the elevator and other technical inventions made the high-rise office tower possible, it soon became profitable for the building owner to rent out parts of the volume to various companies. In the course of time this distributed interior subdivision was perfected both technically and legally. In the US, and increasingly across the world, the occupant company rents empty floor space and has a designer of its choice design a layout while a designated fit-out contractor will install it. The building's owner remains in legal possession of both the collective base building and the custom fit-out, but design control of the latter is delegated to the occupant thereby creating a two-level hierarchy.

4.4.2 The Shopping Mall

A similar development took place in the design and construction of the shopping mall in the mid-twentieth century. Its public spaces are centrally planned and maintained. Empty space is made available for retail to be fitted out by companies who are thoroughly familiar with their customer's needs.

4.4.3 Two-Level Apartment Buildings

A network of academics, practicing architects, managers, and politicians has advocated and implemented the two-level approach in residential construction for decades. It was formalised in 1996 in Tokyo as the W104 Open Building Implementation, a commission within the CIB (International Council for Research and Innovation in Building Construction). The group continues to meet every year in a different country to discuss research and executed projects.[2]

However, where professional power is weak, age old bottom up control re-asserts itself in new ways. In Moscow, in recent years, developers built upscale apartment buildings that were expensively equipped and decorated, ready to be occupied. They found that first buyers had their new property entirely emptied and new fit-out installed by a designer and builder of their choice. Appalled by this wasteful process, and seeing an opportunity to reduce costs and risk, developers began to sell 'empty' or 'free plan' buildings, leaving their customers to take care of

[2]See "*Residential Open Building*" by Kendall and Teicher published by E and FN Spon, 1999, as well as a more recent series of about 80 executed projects collected by Prof. JIa, Beisi, of Hong Kong University, available online: (http://open-building.org/archives/booklet2_small.pdf).

their own interiors. Hundreds of such ‘empty’ buildings for the upscale residential market are on record in Moscow and other Russian cities.[3]

4.4.3.1 The Gated Community

Hierarchical field control is found in the emergence of ‘gated communities’. Worldwide, upmarket neighbourhoods have fenced in their collective territory as a ‘bottom up’ response to municipal inability to offer security and service to its citizens. Urban designers tend to criticise the concept for reasons that are unclear. After all, a modern high-rise apartment building is no different in terms of field control hierarchy from the horizontal gated community. I suspect urbanists see the gated community as a partial privatisation of what they consider to be their field of action. Moreover, as we have already seen, gates jar with the professional ideology of free flowing space that leaves territorial ownership invisible.

4.4.4 The Informal Sector

Whenever the individual house is on its own lot we have a unit of traditional field control. This is still the case for the majority of built environments across the world. Obviously, personal field control is alive and well where affluent citizens can afford to own both land and house. But much more significant are the extensive stretches of land around major cities in the less affluent areas of the globe where people build for themselves. In many cases, do-it-yourself production, often on land inhabited without legal ownership, encompasses more than half of the housing stock of cities such as, for instance, Cairo, Rio de Janeiro and Mexico City. This kind of settlement is labeled ‘informal’ by politicians and the professional world, and usually tolerated grudgingly if not actively opposed.

It is worth noting that these self-build processes make use of the latest technical products: cement, steel reinforcement rods, sanitary and kitchen equipment, sheet glass, roofing materials and all manner of piping and wiring find their way from the sophisticated industrial sector to the informal market, where products are bought piece by piece to be installed in a house that may take years to be completed—and will often be expanded repeatedly after completion to cater for a growing family. If any proof is needed that small scale field control is compatible with contemporary industrial products we need look no further.

[3]Bart Goldhoorn in: “*The Free Plan, Russia’s shell-and-core apartment buildings*”. A-fond Publishers, 2001.

4.5 Fine Grained Field Control and Sustainability

Perhaps the most important argument for encouraging a hierarchy of field control is found in the recognition that it is the basis for environmental sustainability. The lower levels of such a hierarchy enable a fine-grained structure of small control units that can adapt efficiently and quickly to the latest technology, as well as to new social trends. The higher levels of the control hierarchy secure longevity and stability by taking care of what can endure. I cite three new initiatives that move in that direction:

4.5.1 Long Term Investment

Frank Bijdendijk, former director of a not-for-profit housing corporation in Amsterdam says that two conditions must be met to ensure long life for a building: that occupants are free to change and adapt their own units, and that they love the building they share. Buildings that people love, he argues, will not go away. He calls such buildings ‘Solids’.

Bijdendijk decided that his company’s long term ownership of buildings justifies higher initial investment that will pay for itself over time. Assuming a use-life of a century allows initial investment in higher quality design, materials and detailing. An auction of empty floor space for rent in the first building they designed according to this policy yielded the necessary income for its upkeep,[4] supporting Bijdendijk’s theory. Of course, how we can predict that people will love a building remains to be seen. We must learn about that over time when feedback from individual users will help us to find out what people really like in a given case. Without that feedback we will remain in a professional echo chamber.

4.5.2 The Long Life Housing Act in Japan

In December 2009 the Japanese National Legislature passed a law to encourage a lifetime of up to two centuries for residential construction. The law includes a document listing the technical conditions that must be met by home owners to receive a substantial tax break. These technical requirements are based on the view that a contemporary building is a composition of sub-systems that each have their own use-life. Ideally, these systems should be combined in such a way that each can be replaced over time with minimal disturbance of other sub-systems. The use-life of sub-systems is either determined by wear and tear or by inhabitants’ preferences. Examples of the latter are kitchen and bathroom systems that must yield to the more

[4]This first ‘Solid’ is located in Amsterdam West and was designed by architect Tony Fretton for the not-for Profit Housing Corporation “Stadgenoot”.

attractive look and feel provided by newly available products. An example of a sub-system whose use-life is determined by wear is the vertical main drainpipe in an apartment building, rated by the 2009 Act as having an ideal lifetime of 50 years. To facilitate its replacement, an extra space must be available in the utility shaft for a new pipe to be put in place before the older one is taken out. Moreover, that shaft must be accessible from a public corridor or hallway near the apartment entrance because it belongs to the public realm of a collective building. In short, this law demands no technical innovation, but the sophisticated design and management needed for hierarchical field control.[5]

4.5.3 A Fit-Out Industry

The drive for a truly sustainable environment has spawned a large number of inventions, as the industry searches for materials and sub-systems that perform according to current sustainability criteria. To have a meaningful impact on real world conditions such inventions must reach the existing stock of dwelling and work units. To make this possible, three conditions must be met: each such unit must have a replaceable fit-out, it must be a single control unit so that its renewal does not depend on a collective or centralised control, and it needs an industry that can replace its fit-out—in whole or in parts—efficiently and speedily. The first condition can generally be met with state of the art systems. The second condition means that the larger apartment or office building must have at least a two-level control hierarchy that allows the single dwelling or work unit to change independently. The third condition, by and large, has already been met by most office buildings and retail stores, but for apartment buildings a new dedicated fit-out industry is needed.

The first fit-out company dedicated to the renovation of extant housing stock is NEXTINFILL in Japan, initially part of Sekisui Heim housing division but now an independent company. Developers working on renovation projects have begun to sign contracts with this company to do the fit-out, one-at-a-time, when a unit changes hands. NEXTINFILL is also active in new projects, in which the units are usually identical. But clients who buy one for immediate occupancy will be able to adapt it over time when needed. Those who desire a custom fit-out design will prefer to buy space in an empty base building to have the fit-out industry serve them individually.

The potential market for this new industry is substantial. The cost of a fit-out replacement is roughly comparable to the cost of the cars owned by the inhabitants

[5]Prof. Kazunobu Minami of Shibaura Institute of Technology reported on the “Long Life Housing Act” at the Open Building conferences in Noordwijk, the Netherlands, in 2010 and in Bilbao, Spain, in 2011.

and a 20-year use life for a fit out package is generally assumed reasonable. That makes for a fit out industry which is comparable with the car industry in terms of market size and financing of the product.

That fit-out industry makes a sustainable environment possible where each dwelling unit is individually capable to accept the latest technical improvement as soon as it is available. Such an environment will have a complexity comparable to historic examples.

Amsterdam, part of 20th century extension. KLM Aerocarto

Tokyo, view from a high-rise building

Hong Kong, part of a 40 story apartment building.

4.6 Design for Everyday Environment

Everyday environments demand that architects and their clients accept conditions that are fundamentally different from those that framed their work in the past. Whereas traditionally *change over time* has been the enemy of architectural creation, we now must embrace it as a fourth dimension to work with. It used to be the sign of avant-garde design to make each construction entirely different from any other one, while now the aim must be to share values with our peers to achieve coherence between designs and their larger environment. Full ‘top down’ control is seen as a necessary means to achieve quality but, as discussed earlier in this paper, a healthy living built environment needs multiple levels of design control.

Various architects have decided that distribution of design control offers opportunities for a new kind of architecture. Their executed works encourage ‘horizontal’ variation and introduce new ‘vertical’ relations. For our purpose, stylistic considerations are not the issue and can vary greatly, but the methodological aspects exhibited by the following cases are of interest, and represent a new way of working:

4.6.1 The Continuous Base Building

In the early 1970s architect Frans van der Werf built the ‘Molenvliet’ residential neighbourhood following the two-level approach, separating a ‘base building’ for long term use from short term ‘fit-out’ of the individual dwelling units inside. He designed a single low-rise high density base-structure that was deployed as a continuous urban framework with which he shaped a variety of urban spaces like streets and courtyards. This could be done without monotonous repetition because the resulting urban spaces could vary in size and shape while the inside of the structure and parts of the facades could vary over time in response to user preferences. In this way of working the continuous base structure transcends the building level to become a design tool on the urban scale. It suggests a new way to do very large projects that are nevertheless fine grained and invites a new kind of urban design. The Molenvliet project in the city of Papendrecht, the Netherlands, was the first fully executed Open Building project for a not-for-profit housing corporation that made floor space available for rent. Inhabitants could determine the size and location of their unit and take care of its interior fit-out. Virtually unknown in the Netherlands the project is still visited by architects from abroad. Frans van der Werf has since executed some eight other Open Building projects.

4.6.2 3D Urban Design

Today we build single buildings that house populations equal in size to a Classical or Medieval town. For all practical purposes these structures act as three-dimensional urban frameworks. In Japan, professor Yositika Utida was asked by the Osaka Gas Company to lead a team to design the ‘housing for the future.’ Embracing the ‘two-level’ approach, he considered his urban block size base-building design to be what he called ‘Three Dimensional Urbanism.’ His team conceived of a carefully worked-out scheme of pedestrian public circulation connecting a communal garden on ground level with another one on the roof. The dwelling units could vary in size and be fitted out individually. In line with the urbanist analogy, Utida invited thirteen professional architects to design the individual residential units after the completion of the collective structure.[6] This division of design tasks, one directly serving individual households and the other the collective of inhabitants, nicely makes the point that inhabitant control is not necessarily a matter of do-it-yourself action.

4.6.3 The Three-Level Institutional Building

Architect Giorgio Macchi saw in the distinction of levels of intervention an opportunity for a radically new project management model. As Chief Architect of

[6]Osaka City Next 21 experimental housing project. 1993. Design: Prof. Yositika Utida, Prof. Kazuo Tatsumi, Associate Prof Seiichi Fukao, Associate Prof. Mitsuo Takada. Arch. Shinichi Chikazumi and his Shu-Ko-Sha Arch. and Urb. Design Studio.

the Kanton (province) Office of Properties and Building in Bern, Switzerland, he acted as client for the province's public buildings. When asked to lead the design and construction of a new intensive care hospital he introduced a rigorous separation between the 'primary system' that had to last a very long time, a 'secondary system' for interior spatial distribution that would remain unchanged for less than 20 years, and a 'tertiary' system for medical equipment to be used for up to 5 years. First, a competition for the primary system was called without any program given other than the amount of floor space needed. After the construction of the winning scheme had started, ten architecture offices with experience in hospital building were asked to compete for the design of the 'secondary' and 'tertiary' systems. The rationale for this approach was that designing and building a hospital takes an average of 7 years, which renders any program written in the beginning obsolete halfway through the construction period. Moreover during the lifetime of the hospital costly adjustments and changes were to be expected every few years. The separation of levels of intervention would reduce time and costs during both construction and renovation. On the experience of this project the entire Kanton Building Office administration was turned around to routinely apply the separation of levels approach for all buildings under its supervision. So far more than twenty projects—university buildings, health care, housing and other types—have been realised using this strategy.[7]

4.6.4 Open Building Design Management

When a developer wants to offer custom-designed apartment units, a well conceived data management is vital to making the two-level system work well. In 2002 a competition was called by the Helsinki municipality for an Open Building project to be executed in a coastal extension known as "Arabianranta". The winning proposal was submitted by Esko Kahri Architects in close cooperation with Tocoman data processing company. Together they submitted a design and also a data processing system that could help would-be inhabitants to design and budget their individual units, and pass on the necessary technical specification to the builder. The Sato real estate development company took on their winning scheme, most likely not expecting financial gain from an experimental design. However, when the project was completed—in time and within the budget, with all units sold and custom designed—Sato had made a profit and offered a contract to Kahri and Tocoman to continue this approach. Recently in 2013, architect Kahri was invited by Hartela Construction Company to participate in a competition as OB expert. Their proposal

[7]INO intensive care hospital, Bern, Switzerland. Primary system 1997 by Peter Kamm and associated Architects. Secondary and tertiary systems by Itten Brechbuehl Architects. See also Kendall, Stephen, "Open Building: Healthcare Architecture on the Time Axis" in *Sustainable Healthcare Architecture*, Guenther, Robin and Vittori, Gail. Wiley and Sons, 2008.

was selected for the very large and long term FINNOO urban development project which is expected to take 15–20 years to complete.

4.6.5 Sharing Values

In the Netherlands a practice has emerged in which a coordinating architect is asked to work out an overall urban design and supervise the work of fellow architects invited to build parts of the scheme. The coordinator's task is to make sure that their cooperation produces a coherent result. This kind of 'horizontal' professional cooperation has mostly to do with establishing shared types, patterns and other qualities to frame the design of individual buildings.

A paradigmatic example of this approach is a neighbourhood of 1500 houses for which arch. Henk Reijenga was asked to work out an initial general scheme and supervise its execution. For the architecture level of design he defined twelve 'types' of houses to be built, including row houses, canal houses, free-standing houses and duplex houses of various dimensions.. He then invited five architecture offices to design two variants for each of the twelve types, after which he distributed the resulting designs in the larger scheme, making sure to mix houses from different architects in a same cluster or a same street. They then collectively decided on seven colours for bricks, a single slope for roofs, three types of roof tiles, a number of entry doorway types and other details to be adhered to. The pre-selection of house types, components and materials made an efficient execution by the builder feasible, while no two of the 1500 houses are exactly the same. Each house has its own identity within a coherent, and sustainably built, urban fabric. In the middle of the recent recession the neighbourhood was quickly occupied and financially successful.[8]

4.7 Cultivating Complexity

Modernism's explosion of science and technology has unleashed tremendous energies and produced urban environments of unprecedented size and composition. But as configurations of control patterns, these environments are less complex, less socially grounded and less use-responsive than we might expect. The 'hardware' we are making for our cities appears to be in conflict with a society that prides itself on individual freedom of expression, action and choice. I have suggested that we find ourselves in the middle of a long period of transition in which design and management are slowly learning how to match technical power with social structure

[8]Westpolder-Bolwerk project, Lansingerland municipality, the Netherlands. Urban design and architectural coordination by Henk Reijenga Architecture and Urban Design bv.

and stimulate the human energies of settlement that have always shaped our built environment. The examples in the previous section are evidence of new design processes that can lead to a more socially driven interaction between people and their habitat, resulting in a sustainable architecture that adequately serves contemporary social complexity.

It has often been pointed out that erecting a contemporary building of any size, given the variety of materials and the many subsystems it combines, is a demanding process. This is not to say that construction in past times was primitive. To the contrary, historic building techniques could attain marvelous levels of sophistication honed by generations of practice. Technical sophistication and social structure reinforced one another. Our forefathers would be amazed by the number of material sub-systems that must be brought together in even an ordinary contemporary building. They might well sympathise with our struggle to keep the technical job under control. It is therefore more correct to say that, so far, technical *complications* have prevented us from arriving at the *environmental complexity* that historic environments display so effortlessly.

The usual answer to the lack of inhabitant control is that we do not yet have the advanced technology to deliver a more responsive environment. But the new ways of working mentioned in this paper *are* already responsive to occupant intervention and desire for choice, and have all been successfully executed with currently available technical means. However, they all required an overhaul of ingrained design and management habits. The problem is not the hardware, but the profession's reluctance to re-organise itself.

We instinctively resist change. We stick to our ways of working for the good reason that one becomes vulnerable and mistake-prone when one can no longer rely on the familiar. Inventing new technology is also much more attractive than dropping acquired habits and questioning procedural conventions. In building practice, moreover, every professional task is intimately connected to what others do, so changing how one works demands a willingness by other parties to cooperate in the new. Thus, the impulse is to continue working the way we are used to even when evidence shows a better alternative.

While society has progressed substantially, our management and design methods have become outdated. Early last century, when lack of decent shelter for a substantial proportion of the population challenged the professional world and labour was relatively cheap, solving the housing shortage relied on workers trained to handle a specific subsystem. Carpenters, plasterers, painters, plumbers, installers of heating systems or ventilation ducts, to name only a few of the sub-systems to be installed, moved from one unit to another repeating the one act they were familiar with. Each team was preceded and followed by other specialists doing something else on the same site. The choreography of these various actors, some of whom had to return at a later stage but none of whom saw through the entire end product, became a major management task. This repetitive and fractured mode of operation was erroneously inspired by the conveyor belt production of the original Model T-Ford automobile as the hallmark of an efficient industrial production. Applied to building, it required the exclusion of direct inhabitant involvement, a prerequisite which has shaped professional thinking for more than a century. As a result, we struggle as a profession to imagine how inhabitant control could contribute to the quality of built environment.

It has been demonstrated that, with the more advanced subsystems available today, a team of two or three trained multi-skilled workers can fit out an entire dwelling unit in a couple of weeks. This was convincingly demonstrated in an Open Building renovation project for a not-for-profit housing corporation in the town of Voorburg, the Netherlands more than three decades ago. The new fit-out industry in Japan follows this more efficient and cost effective way of working, using available hardware and up to date logistic capacity to do the job. Moreover, there is no need for the repetition of a single design since each dwelling unit is treated as a project in its own right, matching the basic control unit of the household, that can differ from any other one.

The fact that small-scale control in today's big projects demands first of all delegation of design control does not diminish the importance of industrial innovation. To the contrary, when the dwelling unit and the work unit are active control fields they stimulate innovation, as well as reward it by individually absorbing technological advances without the controlling mediation of central management. User control does not depend on new technology but successful technical innovation does depend on fine-grained user control.

Nevertheless, while wholesale adoption of this alternative is technically possible, it demands more than just yielding reluctantly to a new reality that can no longer be ignored. A fundamental—and willing—cognitive re-orientation of the profession is needed.

Design and technology cannot make built forms live: only occupancy can. Fine-grained field control at the scale of the household and the work unit will breathe life in the entire environmental body. Enabling the energy of occupancy to do its part must become an essential subject of professional skills. When we respect the built environment as a truly living entity we can make it bloom. It will pay to see ourselves not only as builders who make environmental things but also as gardeners who know how to cultivate a living field.

Chapter 5
The Fourth Sustainability, Creativity: Statistical Associations and Credible Mechanisms

Bill Hillier

Abstract In this paper, it is argued that over and above the three sustainabilities of energy, society and economics, there is a fourth: creativity. It poses the question: can credible mechanisms be identified through which cities are more creative than other forms of settlement, as statistical evidence suggests? It proposes that just as mechanisms can be identified linking the generic form of cities to 'spatial sustainability' for the first three, mechanisms can also be identified for creativity through the ways cities generates social networks. But whereas the first three sustainabilities are consequences of the form of the city, the fourth sustainability, creativity, is argued to be the reason for the form.

5.1 Creativity: The Fourth Sustainability

Cities have been getting a good press in recent years. This is quite a turn round, since for a century and a half it has been widely believed (with exceptions that are too familiar to mention) that large dense aggregations of people were so unlike the ways in which societies had previously been organised in space, that they were likely to be in themselves socially negative. While this view prevailed, there was little concern as to what we might be losing if new communications technologies made cities unnecessary. Now cities are more and more seen as positive, not only because they are seen as sustainable in many senses, but also because the very factors of scale and density which had been associated with social disorder and malaise, are now seen also as key factors in the intellectual creativity through which cities become drivers of economic and social development (for example, Bettencourt and West 2010, but more recently McKinsey Global Institute (2012) (http://www.mckinsey.com/insights/urbanization/us_cities_in_the_global_economy) and Florida (2012) (http://www.citylab.com/work/2012/11/cities-denser-cores-do-better/3911/).

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If cities are somehow in this sense creative, then this must surely become, over and above the environmental, the economic and the social, the fourth sustainability. But what is it about cities that 'creates creativity'? We are familiar with arguments about how companies benefit from spatial aggregation, but there is little to suggest theoretically why spatial aggregation in cities, rather than, say, out of town business parks, should lead to more creativity. Space syntax doesn't seem to help with this question. It tells us something about how cities work, but not whether or why we need them. It is not clear if space syntax could ever help. If cities do somehow 'create creativity', then it must surely be by influencing social networks, and these seem largely driven by non-spatial factors which do not seem to map significantly onto the micro-to-macro scale analysis we associate with space syntax.

In this paper, it will be suggested that the situation is not so negative! At least a theoretical argument can be put together which links different kinds of emerging evidence into a coherent spatial picture of why and how cities might be more creative than other ways of spatially distributing the same number of people. The paper will first sketch the space syntax view of the city as space, and review the system of credible mechanisms through which, it argues, cities go from being collections of buildings to living social, economic and cultural systems with a generic underlying form (set out more fully in Hillier 2012a, b). This system reflects the interaction of micro-economic and social factors, set against the background of minimising distances, and so in this sense, expresses the interaction of the three main factors in sustainability, suggesting that evolved cities manifest a 'spatial sustainability' from which it was argued in (Hillier 2009) we have much to learn. It will then address the fourth sustainability: creativity, and pose the central question: there is a statistical association between cities and creativity, but are there credible mechanisms linking one to the other? It will be argued that the generic form of the city that gives rise to 'spatial sustainability', also relates closely to credible mechanisms through which different kinds of social networks are generated in cities, and this suggests ways in which the spatial form and functioning of cities could be related to creativity.

5.2 Syntactic Structures in Cities

First, let us look at the structural picture of the city brought to light by space syntax analysis of street networks, and how this generates the 'living city'. The basic unit of analysis in the syntactic analysis of cities, is the street segment between junctions. We calculate the potential of each for to-movement from all others by mathematical closeness (or *to-movement* potential), and for through-movement between all others, by mathematical betweenness (or *through-movement* potential), and we do so under three definition of distance—shortest paths (metric), fewest turns (topological) and least angle change (geometric), and under varying metric radii from each segment—so a typical measure would be *least angle betweenness at a radius of* 2 km. Comparing theoretical to and through movement at different radii with real observed movement show that both predict movement, usually with an r-square between 0.5 and 0.8, though which measure is best varies with morphological circumstances. Prediction is generally best with the least angle definition of distance, and least good with the metric definition. Different scales of movement also correlate best with different radii of the measures, with a radius of about 400 m for pedestrian movement in areas like market places, 800–1200 m for normal urban pedestrian movement, 3–5 km for cycling, and without radius restriction for vehicular traffic. The best measure across all scales is usually one that combines closeness and betweenness, and called *normalised choice* (Hillier 2012c), which also allows numerical comparisons between systems of different sizes.

The relation between the urban grid and movement is the generator of the process by which the different parts of the city acquire differences in the form and level of activity. Locations which the grid has made movement-rich attract land uses which need movement, which in turn generates more movement, setting in train the process through which cities acquire their generic dual form of a foreground network of linked centres at all scales, set into a background network of largely residential spaces. Figure 5.1 The foreground network is driven by

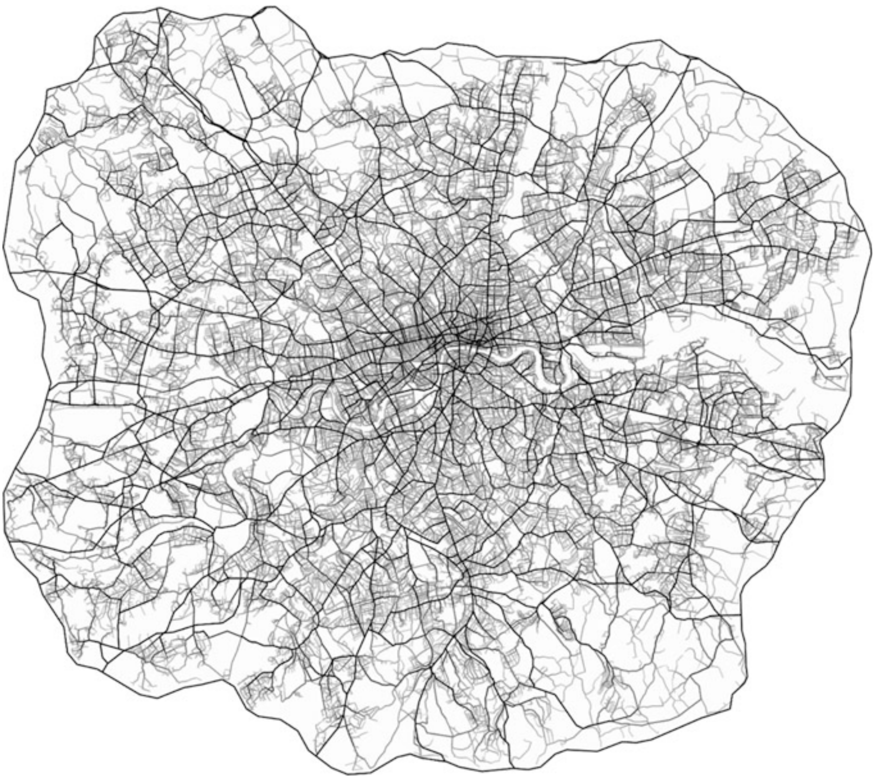


Fig. 5.1 London within the M25: log betweenness with no radius restriction

micro-economic activity, and so concentrates movement, and can be seen as morphogenetic since its aim is to bring people together and develop, the background network by socio-cultural factors, and diffuses movement, and can be seen as conservative, since it aims to structure movement and reproduce existing social patterns. The foreground grid also generates the links between a city and its neighbours in the local system of cities, and the background grid will normally depend on these connections rather than having its own.

5.3 Pervasive Centrality

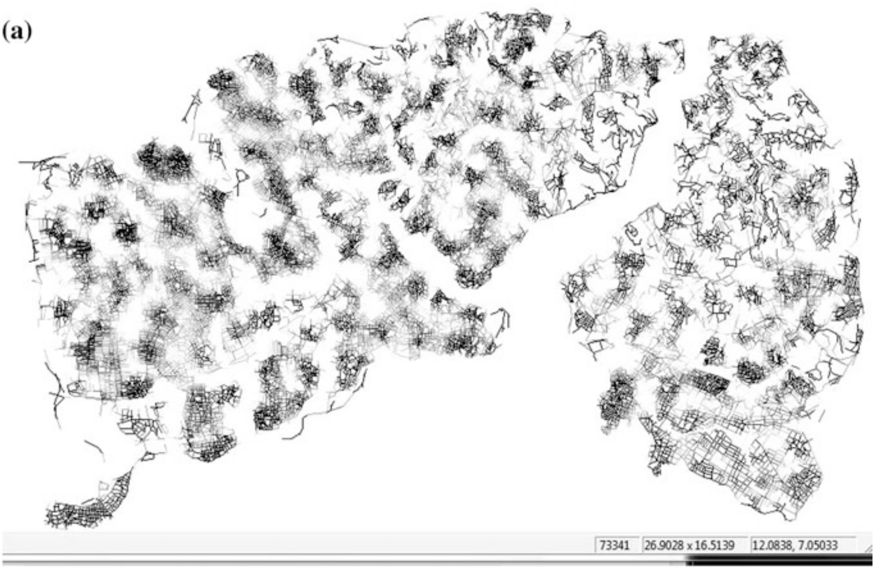
Space syntax purports to be, in effect, a testable (and constantly tested through applications!) structure-function theory of the city, relating the geometry, topology and metric scale of space to multi-scale movement, land use patterns and densities. A key outcome of the process it describes is a pattern of centres we call pervasive centrality, by which we mean that centrality functions such as retail pervade the urban grid at all scales, creating a far richer and complex pattern of centralities even than envisaged in concepts of polycentrality. It comes into existence through something like the following process (again this is set out more fully in Hillier 2009). Every centre has a centre. It starts with a spatial seed, usually an intersection, but it can be a segment. The seed of a centre will have to- and through-movement potentials at a range of radii, but at least covering both local and non-local levels. The spatial values of the seed for the centre will establish what we can call a fading distance from the seed which defines the distance from the seed up to which activities like shops will be viable. This is a function of metric distance from the seed proportionate to the strength of the seed. The centre will grow beyond the fading distance established by the initial seed to the degree that further seeds appear within the fading distance, which reinforce the original seed. Again these can be local or global, and stronger or weaker. A centre becomes larger to the degree that it is reinforced by what are, in effect, by new seeds created by the grid which allow the shopping to be continuous.

Centres then expand in two ways: linearly and convexly. Linear expansion, the most common case, will be along a single alignment or two intersecting alignments, and occurs when the reinforcers are more or less orthogonal or up to 45° to the original alignment or alignments. Oxford Street in London, for example, is a strongly linear east-west centre, shaped by the series of powerful north-south alignments which intersect it, for the most part at 90°. Convex expansion will be when the shopping streets form a localised grid, and this occur when reinforcers occur on the parallel as well as the orthogonal alignment. So centres vary in the strength of their local and global properties and reinforcers, and the balance between them will tend to define the nature of the centre. Most centres will be in some sense strong in both in local and global terms, but differences in the balance between local and global will be influential in generating the scale and character of the centre. Centres also grow or fail, of course, through interaction with neighbouring centres at different scales, and some potential locations for centre fail to be realised due to the existence of centre close by, but the way in which the urban grid evolves tends to ensure that seeds for potential centres occur only at certain distances from each other.

The centres that emerge from this process have certain critical properties. First they are *multi-scale* in the precise sense that they feature strongly on to- and through-movement at both more local and more global scales. This can often be shown simply by the differences into- and through-movement values at different radii on the different segments that make up the key line or lines of the centre (see Hillier 2009). At the same time, most centres peak at a particular scale, though what this scale is, or the range of scales at which a centre is strong, will vary from centre to centre. Because they have these properties, centres must be seen as linking the local to the global scale (though only some at the scale of the whole city) rather than being simply ‘local centres’, though of course they are that too. This is vital to our understanding of how the foreground and background networks operate in cities.

Second, the fact that centres at all scales either have, or acquire, a smaller scale ‘intensified’ grid (Hillier 2000) allows us to bring to light a remarkable metric dimension to cities. If instead of using least angle distance in our measures, which identifies the linear patterns that correlate with movement and land uses, as in Fig. 5.1, we use shortest path, or metric, distance in relation to to-movement potentials, we identify not linear patterns but a two dimensional periodic patchwork, which looks like an area structure, one which varies in scale according to the metric scale of the measure. For example, Fig. 5.2a is the periodic patchwork identified by calculating mean metric depth from the centre of each street segment to all others within 500 m for Istanbul. This can be represented in a ‘mountain scattergram’ Fig. 5.2b in which the x-axis is metric integration at the scale of the whole city (and so runs from the geometric centre of the city on the left to the periphery on the right), and the y-axis is local metric integration at a scale of 500 m. The peaks of the ‘mountains’ are the local centres of areas, at different scales according to the size of the mountain. If we increase the radius, the mountains become less peaky, but remain mountains corresponding to the areas defined at that radius. In most cities, it is this multi-scale *periodic structure* that seems to define the —equally multi-scale—sense of urban areas, rather than clear physical or spatial boundaries, and it is this kind of structure which often allow cities to combine *spatial continuity* with area differences (Hillier 2000; Hillier et al. 2010).

(a)



(b)

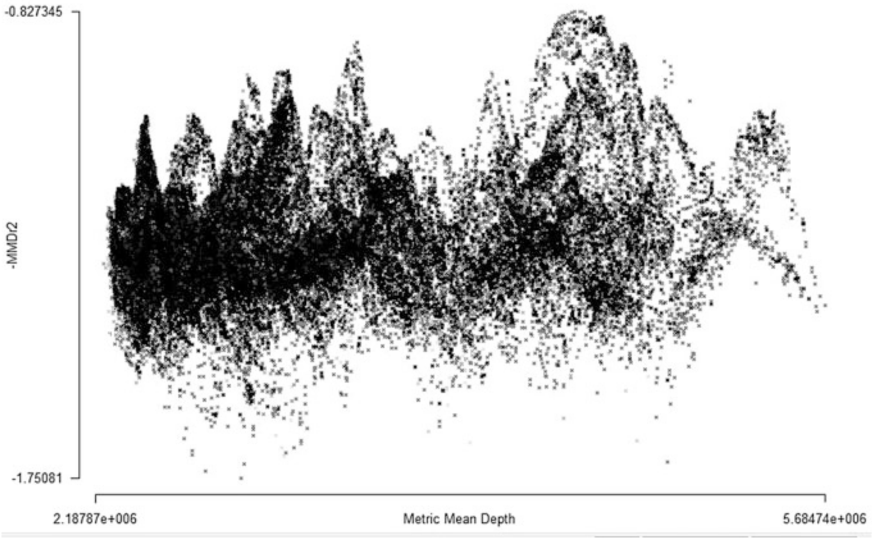


Fig. 5.2 **a** *Top* Istanbul: mean metric depth at a radius of 500 m. **b** *Bottom* Istanbul: 'mountain scattergram' with mean metric depth without radius restriction on the x-axis (so centre to edge) and mean metric depth at 500 m on the y-axis. The *tops* of the 'mountains' are the centres of the areas identified in (**a**)

5.4 Spatial Sustainability

These mathematically defined, but functionally potent patterns show us that the city is not a collection of well-defined cellular areas linked by a superordinate master network, but a much more complex spatial network in which the relations between scales is primary at all levels. More critically, the different patterns of land of uses associated with the two components of the dual grid, show that the foreground network drives micro-economic activity by focusing movement while the background reflects social and cultural restrictions by diffusing it. More simply, the dual grid reflects the fundamental distinction between work and residence that shapes all urban lives. This is perhaps why it is the dual grid that seems to define the city, and perhaps has always done so. In view of the near universality of this form, it could perhaps be conjectured that it was the discovery of this efficient way of linking of the economic and social functions that made the city possible in the first place. As we have already noted, from the point of view of sustainability, the generic form of the city seems to be the product of interaction between micro-economic factors structuring the foreground grid, and socio-cultural factors structuring the background grid, against a general background of optimising accessibility of all parts to all others, so the generic city that has evolved could be expected to exhibit what we might call *spatial sustainability* (Hillier 2009).

5.5 The Fourth Sustainability

But what about the fourth sustainability: creativity? The starting point, as suggested earlier, is that if there is a mechanism through which cities become more innovative than other forms of spatial existence, then it is likely to involve social networks. If this mechanism involves space, then it would suggest some relation between social and spatial networks. This seems unpromising. Social networks seem only trivially to interact with spatial networks at the syntactic level of the street system. Most relations outside families are based on 'interest groups', which are by definition non-spatial. So if it is a truism to say that cities exists to create contact between people, what kind of contact can this mean? It can hardly be just meeting in the street. That would involves too few people, as streets, however busy, are largely anonymous. But in another sense there are far too many people in the city—you cannot possibly contact them all, or even a good proportion of them. So what does it mean to say cities are about contact?

In what follows, it will be argued that cities do create social networks, but of two very specific kinds, and that these reflect the dual form and functioning of the urban grid as we have described it. It is in these senses, it will be argued, that cities are about making contact. These processes is so basic, it will be suggested, that if the first three sustainabilities are the consequences of the dual grid, the fourth sustainability, creativity, may be the reason it is there is the first place.

5.6 Recent Research

First, some history. In the early stages of its development, social network analysis was preoccupied with networks than were dense—the contacts of individuals were in contact with each other—and multiplex—individuals were in contact with each other for several different reasons (playing golf, being someone's grocer or cousin, and so on). These were thought to be the characteristics of village communities, which were taken to be in their nature superior to sparse and supposedly anonymous urban networks. Then came Granovetter, who showed that economic opportunity was related not to the 'strong ties' of the dense parts of individual's network, but to the 'weak ties' in its sparser and more diffused parts (Granovetter 1982).

Other work found strikingly comparable results. Particularly interesting from our present point of view was Allen (1977) who showed that innovation in research and development was related not to the intensity of contacts within groups, but to contacts between groups, suggesting that contacts which generated innovation were not those you collaborated with every day, nor those with nothing in common with you, but those at, in some sense, the *right conceptual distance* from you, neither too close or too far. Below I will call these '*contacts of the right kind*'. Contacts of the right kind are those more likely to make links between ideas and generate new ones. Are there ways in which cities can produce contacts of the right kind, more than other spatial arrangements?

We can begin by noting that the idea that dense local networks are socially and economically limiting, and benefits tend to come from more diffused networks, has received remarkable scientific confirmation in a recent paper by Eagle et al. (2010) on communication patterns and economic development. In a study of mobile phone calls in England, forming a graph with 102m nodes and 368m links, it was shown that those living in socio-economically successful areas had networks that were both socially and spatially more diverse, while those in less advantaged areas had networks that were more concentrated socially and spatially. Under-privileged areas did not have lower volumes of calls, but they were more localised and more focused on particular individuals. At the same time, they were denser, with social advantage clearly associated with non-dense (I will call them 'hybrid' below) networks, a finding emulating earlier work by Burt showing that remuneration in an organisation was positively correlated with the number of 'structural holes' (meaning the lack of density) in an individual's network (Burt 1992). It was also found that as the number of an individual's contacts increased, the amount of contact per contact decreased, suggesting again that it is not simply the quantity of contact that matters, but its type.

These results seem to generate an even more serious problem for the idea that cities generate creative networks. If cities do in themselves somehow generate social networks, common-sense suggests we would expect them to be primarily local and dense, reflecting the local scale and spatial closeness of populations. But such networks are associated with social disadvantage. So the questions become: how can the city create spatially dispersed non-dense networks, and why should they do so?

5.7 Seeing Networks Spatially

As a first step towards addressing this question, it is useful to picture social networks in a spatial way, while taking care not to mistake them for literally real spatial patterns. The fundamental unit of urban spatial experience is the isovist, made up of a local convex area, where everyone can see everyone else, and the 'spikes' reaching out into non-local areas where people cannot see each other Fig. 5.3. This has a remarkable resemblance to an individual's social network. There is a convex core where everyone knows everyone else, and 'spikes' reaching farther out into the network, where people do not directly know each other. Noting that there is no standard term for 'spikiness', as oppose to density, I will call the spikes the *hybrid* parts of the network because they originate in idiosyncratic rather

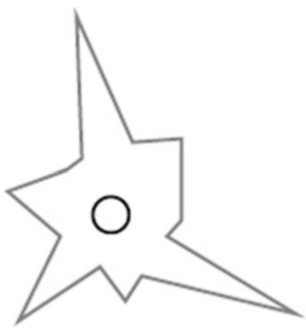


Fig. 5.3 Typical urban isovist with a convex centre and spikes

than shared sources.[1] We can also use the spatial analogy to generate a picture of the whole network. The hybrid spikes reaching out from the dense local groups can be seen as tending to form a socially and spatially more diffused *foreground* network, linking the dense, more localised *background* networks. The spatial and social systems do not of course map onto each other on a one to one basis, but the structural similarity of the two systems is striking, and, as we will see, there is a structural relation between them. At this stage, we can at least begin to think of social networks in the same kind of way we think of spatial networks.

There are some simple, but important, numbers associated with *hybrid-dense* systems. We can think of the everyday intuitable limits of an ego centred network as having 4 levels, 3 from ego, as in, for example: *I met a man whose father knew Lloyd-George*. If we allow each individual to know 9 people, and in one case 3 are dense, so already in the network, and in the other 6 are dense, then at level 3 (the Lloyd-George level) there are 388 people in the more hybrid system and 118 in the denser system. At one more step, the difference is 2331 against 360. We could note that if everyone knows 100 people, and none are dense, then there are 1 million people at the Lloyd George level, and one more step exceeds the population of the UK, and one more of the world. Real world graphs are not of course as shallow as this—the mean distance in the Eagle study was 9.4—but they are shallower than we think, and we should never be surprised to discover indirect connections to someone we meet. But practically speaking, for our present purposes, holding contact volume steady (as evidence suggests we may), hybrid networks should be very much bigger than dense ones.

5.8 Three Interacting Factors

We seem then to have three interacting factors. We have social networks which vary from the hybrid to the dense; space, which varies from the more integrative in the foreground network to the more segregative in the background; and social status, which varies from advantage to disadvantage. We know already that there is a relation between social networks and social advantage, in that socially advantaged networks are more hybrid, and between social networks and space in that socially advantaged networks are more spatially diffuse. Recent results show there are also relations between space and social advantage. A recent study (Hillier and Barnes 2008) covering over 100,000 dwellings in a sector of London showed that house value, as measured by 'Council Tax' (a tax based on house value) correlated linearly and positively with global integration. We also found a relation between space and social advantage at the national level (Hillier and Serra 2014). Using a

[1]The term 'hyrbid graph' is used by Lehmann et al. (2006) to mean a mixture of random and non-random elements in a graph. The term is also used in physics in relation to dynamic systems which exhibit both continuous and discrete behaviour. Neither seems a good reason to avoid this natural term to describe positively a key property in social networks.

syntax map of the whole of the UK, giving syntactic values to every road and street segment in the system, we found that income correlated positively with integration at a radius of 90 km, showing that integration is a key property in systems of cities, as well as in individual cities. We can reasonably assume that the relation between social advantage and space is two way: we construct the relation through the way we build cities, and then space plays a role in perpetuating social advantage. Another key relation shown by the same study is that job density, but not income, correlates strongly with integration at the local radius of 2 km, so, not surprisingly, the areas associated with pervasive centrality.

It is clear then that there is a relation from social networks to space, though it is not clear yet what mechanism could explain this. But there is no notion of a relation between space and social networks, as we would expect there to be if the city plays a role in creativity. The one thing we know the space structure of the city does in and of itself is create patterns of co-presence through movement. If this seems a weak outcome for the massive investment that the city is, we have seen that it is enough to set in train, and maintain, the processes through which collections of buildings become the living economic and social systems we experience. We might then expect these massive patterns of co-presence would somehow create the kinds of social networks that advantage cities, an 'urban creativity' process of some kind. But this idea, as we have seen, leads to paradox. The network patterns associated with social advantage seem inconsistent with what we would expect the effects of the city would be. The problem then is to identify a credible mechanism through which cities can create spatially dispersed networks, and the advantages that seem to come with them? How do cities create networks of the right kind? To take the next steps, we need to complicate our model of what a city is as a spatial and social system, and for this we need to bring in some new theoretical concepts.

5.9 Spatial and Conceptual Groups

The first concept is the distinction between spatial and conceptual groups in society. Households, villages and universities are spatial groups, families, clans and academic disciplines (and 'interest groups' in general) are conceptual groups. Conceptual groups will have a spatial distribution of some kind, but they are defined in themselves without reference to space, whereas with spatial groups space is part of the definition. Now it is a mistake to think that, because they are aspatial in their definition, conceptual groups play no spatial role in society. On the contrary, in pre-urban societies, a principal function of conceptual groups such as clans is to create the non-local relations (such as marrying circles) on which the genetic viability and social interdependence of the society and its cohabiting groups depend. This is why clans are typically dispersed across spatial groups, rather than coinciding with them. From the beginning (as far as we understand it) societies are much bigger than their cohabiting groups, and these are linked in the main by the activities and structures created by conceptual groups (Hillier and Netto 2002).

Modern urban societies do not have clans, of course, but they do have conceptual groups, and for the most part these are related to the division of labour first facilitated by the creation of cities. I think it is safe to call these *knowledge* groups, because what essentially distinguishes them is the specialised knowledge that allows individuals to play a particular role in a functionally differentiated society. So architects, or bankers, or taxi drivers are all conceptual groups defined by some kind of shared knowledge forming the basis of a functional role. Micro-economic activity is essentially interaction between and among members of knowledge groups, so, as with clans, the key effect of the existence of these knowledge groups is, precisely because they are not spatial, to create relations and encounters of a non-local, as well as local, kind.

Reflecting this, social networks for most people will then be made up of two kinds of relations: one we can approximate as 'family and friends', which will be broadly associated with the background residential, and so conservative parts of the spatial network and have some degree of durable density by virtue of being spatial (Goldenberg and Levy 2009); and one we can call knowledge group relations, associated with the foreground micro-economic (or more simple 'work'), parts of the spatial network, which in its nature will be morphogenetic, and being non-local nature will tend to lack spatially induced density.

5.10 Social Contacts and Information

Second, we must distinguish social contacts from information. Every individual is the centre of what we might call a Lloyd George system made up of information up to three steps away. This will not be all information in the system, of course, just some of it. However, from an information point of view, it would mean that the information advantages of the hybrid system over the dense system will be very much greater, since it will search the system all the more quickly. We can also make the distinction between the morphogenetic and conservative aspects of social contacts precise by making an analogy between network structures and the mathematical theory of information, using the distinction proposed by Moles between semantic and aesthetic information (Moles 1958, 1968)—though of course here we will not be talking about aesthetics, but translating the analogy into social contact terms. Moles set out from Shannon's distinction between the redundancy (or structure) of a language, and the information that it can transmit. The latter can be measured in terms of the freedom to choose permitted by the redundancy, and so the degree of unexpectedness in the message. Moles sought to explain why we go to see a play or hear a symphony with which we are already familiar. Moles distinguished between the score or story, which he calls semantic information, and saw as analogous to Shannonian redundancy, since it is always the same and known in advance, and the spatio-temporal performance, which he calls aesthetic information, noting that because it is not known in advance and always varies, it can be regarded as Shannonian information. From the point of view of experience, semantic information can be completely known, and so exhausted, while aesthetic information cannot be. Hence we go.

In Moles analysis, the ‘semantic’ information can be regarded as conceptual, since it is embodied in the signs of the score, while the ‘aesthetic’ information can be regarded as ‘spatial’ since, like speech in contrast to language, it is created and realised in space-time. This allows us to translate the concepts for the structure and formation of social networks. The semantic information, or redundancy, is the existing structure of the network at any point in time as a conceptual structure, and the ‘aesthetic’ information is the originality and unexpectedness of the information (in Lloyd George terms) in space-time created by a new spatial contact. Clearly, the more the network is dense, the more the Lloyd George information will refer to the existing structure of information, and so to the redundancy of the system in Moles terms, and the more the system is hybrid, the more the Lloyd George information will be unexpected, and so constitute information in Shannonian terms. We can also link this to the distinction between spatial and conceptual groups. The pattern of conceptual identity is part of the existing network, and so can be seen as providing a semantic (in Moles terms) basis for contacts, while the spatial contact itself, and the Lloyd George potential this generates, can be seen as the informational content, which can be much richer. This can also involve others who are present at the contact, and will be experienced by ego as additional random information, especially if the system is hybrid, as can be expected. In this sense meeting people is spatially richer than the concept of the network, just as the performance is richer than the score.

5.11 Levy Flights and Brownian Motion

The third concept is the distinction between ‘Brownian’ and ‘Levy flight’ search strategies, as applied to the ways animal predators seek prey. Here what is sought is not prey, but contacts, and so information, of the ‘right kind’. Brownian motion is random local motion, and operates efficiently for predators seeking prey where prey are plentiful in a locality. But where prey are sparsely dispersed, a more efficient strategy is a pattern of movement called Levy flights, made up of a mixture of localised movement coupled to periodic much longer steps. Reasons for the greater efficiency of Levy flights in sparse target situations include both a greater range of search, and a substantially reduced chance of repeating a search in the same space. The aim of introducing this concept is not to enter the debate on how far human movement in general can be regarded as Levy flight or Brownian or neither (Gonzalez et al. 2008), but to suggest some useful conceptual analogies between these concepts and the structure and functioning of the city. In terms of functioning, contacts of the right kind are likely to be sparse and we don’t know where they are, so only an efficient probabilistic search strategy is likely to bring them into contact. More strikingly, in terms of structure, the spatial configuration of the city as we have described it in terms of foreground and background networks, seems to reflect the distinction between Brownian and Levy flight motion to a remarkable degree. The foreground network, with its strong linear relations between local centres, and the highly explorable small scale local grids of those centres, reflects the two components of the Levy flight, while the background network, with its more localised and uniform grid structure, seems more simply Brownian.

5.12 City Space and Social Networks

We can bring these concepts together to conjecture a general theoretical model of the ways in which cities generate social networks, including a plausible mechanism for how contacts of the right kind are generated. The fundamental idea is that the city creates two different types of network, and these reflect both the dual spatial structure of the city, with its integrated foreground and localised background networks, and the dual social network with its hybrid 'integrated' foreground and dense localised background. The model is summarised in Fig. 5.4. The critical step is to distinguish between the two functions of social networks: social stability and morphogenesis, and link them to the spatial and social networks. Social stability in a network will be enhanced by density, in the sense that the Lloyd George information activated by spatial contact will refer to the existing structure of the system, and so constitute redundancy, rather than unexpected 'information' in the Shannonian sense. This then fits naturally into the localised background grid where space supports density. This does not of course mean that everyone locally in the background network knows everyone else, just that a certain proportion of the networks of individuals in the area are likely to be local and dense. Dense groups are in this sense spatial groups, and as such can be generated and maintained by Brownian motion in the background network with its localised structure and lack of local to global spatial connections.

SOCIAL AND SPATIAL NETWORKS: model

form → function ↓	social network	information	groups	space	process	spatial network
stability	dense, (comm-unity)	redundancy	spatial	local	brownian	background, residence
morphogenesis	hybrid, (indivi-dual)	unexpected	knowledge	non-local	levy flight	foreground, micro-economic

Fig. 5.4 Model of the dimensions of variability of urban spatial and social networks

In contrast, spatial contact in the hybrid network will tend towards morphogenesis, since the Lloyd George information will tend to constitute Shannonian information rather than redundancy, due to the hybridity of the network. This then fits naturally into the foreground network where contacts are generated non-locally by interaction among and within aspatial knowledge groups, creating a pattern which resembles Levy flights in the foreground network, with its strong local to global connections, linked to the intense local structures formed by centres. We should note that it is not being argued that human movement takes the form of Levy flights, simply that the pattern of movement in the spatial network created by the contacts among and within aspatial knowledge groups will take a form, and have an effect, comparable to Levy flights in that it will be made up of non-local jumps as well as local contacts in those locations, and so will act as though it were an efficient search technique for an unknown objective. In general then, contacts in the background network will tend to reproduce existing relations, and so tend to social stability which the spatial form and its residential function already suggests, while those in the foreground network will tend to generate new relations and so morphogenesis, again which its spatial form and its micro-economic function also already suggest.

Within this process, we can begin to see how the discovery of contacts 'of the right kind' will be facilitated. The simple fact that non-local, work-related contacts are made between and within knowledge groups sharing some common problem definition, means that there is a good probability that many will be at about the 'right distance'. Also the fact that the potential population addressed by this process will only be a small fraction of the total urban population (though substantially more than the people of the right kind that you might bump into on the street—though this need not be excluded) makes the search numerically both worth-while and viable. Most important perhaps is the scale and concentration of micro-economic activity, since this will define the scale and accessibility of the field accessible to easy direct contact. This seems likely to be related both to Florida's finding (Florida 2012) that the spatial density and concentration of centres, is a strong factor in economic success, and also the finding in (Hillier and Serra 2014) that the level of economic activity as measured by job density is strongly related to local spatial integration.

These properties form a context for a contact process in the foreground network in which the hybridity of the system, linked to the quasi-levy flight structure of search, mean that the unexpected information generated by spatial contacts will be maximised. To this can be added the likelihood that contacts are likely to also generate random add-ons in the form of others who are also present at the contact, and these are also a likely to take the form of unexpected information through hybridity rather than known information through density. So the structure of the system of contacts generated by knowledge networks will increase the probability of finding contacts of the right kind whose whereabouts are unknown, and the bigger and denser the city, the richer and more numerous will be both the contacts of the right kind and those seeking for them. So, given an efficient search process through contacts, the bigger the system the more successful it should be in generating networks of the right kind, not necessarily with respect to particular individuals, but probabilistically, with respect to the working population as a whole. The morphogenetic pattern of contact which bring this about is fundamentally driven by the spatialisation of the aspatial knowledge groupings, not by local dense spatial groupings. This is why economic success is associated with non-local rather than local measures. It reflects how cities work economically to develop and innovate, rather than how they work to create social stability.

5.13 Summary and Conclusions

To summarise, then, in the background network, social contacts will tend to be dense, reproduce existing information, and affirm spatial groupings which maintain contact locally by Brownian movement. In the foreground network, social contacts will be hybrid, generate new information, affirm aspatial knowledge groupings, and maintain contact non-locally by movement which emulates the Levy flight pattern. The larger and denser (in the spatial sense) the system becomes, and the more interactive it is, the more likely it is that links 'of the right kind' will be there to be discovered. We see then that there is a relation between the spatial and social foreground networks, as there is between the social and spatial background networks. Taken as a whole, the spatial nature of the city supports the development of both social stability and morphogenesis through social networks, and morphogenesis will lead, on a probabilistic basis, to contacts of the right kind.

It can be argued, then, that one of the fundamental effects of the city is to create non-local connections, and so to overcome distance. In this sense it can be compared to pre-urban societies where the form and nature of society is given by the devices through which society overcomes space to inter-relate a region of separate spatial groups. The difference is that whereas in pre-urban societies the space of a sparse population was overcome through the structure of social reproduction (devices like clans and age sets), in cities the space of a highly aggregated population is overcome through the structure of production. This is perhaps the basic difference between cities and other forms of human spatial organisation. In this context, it is striking, perhaps, that denseness gives a network meaning to the concept of community through the interrelatedness of a group of people, while hybridity gives a network meaning to individuality, in that an individual's network it likely to be unique, and held together only by that individual.

This is only a theoretical model, of course, but it is consistent with the many kinds of data we do have. It suggests at least that there is a remarkable analogy between the generation and functioning of social networks and the dual spatial structure of the city. We might ask then, what causes what? While in the case of the credible mechanisms through which cities go from being collections of buildings to economic and social systems, a causal role can be assigned to space through its effect on movement, in the case of the formation of social networks this seems not to be the case. We do not have a credible mechanism through which spatial structure can 'cause' social networks. Networks are created by economic and social activity, but take a structural form which reflects the spatial form of the city, so we find a profound relationship between the two kinds of network, but on a structural, rather than one to one, basis.

It seems much more likely, then, that the spatial structure of the city has evolved in response to the need for these networks, rather than vice versa—that the urban spatial structure has been called into existence to facilitate a close but distinct relation between social stability through residence and morphogenesis through work. After all, whatever else the city is for, it exists to create an economic system —and though the relation to residence, this becomes a populated economic system. We can say perhaps that if cities exist to create certain kinds of social network, and this is why they take the form they do, the first three sustainabilities are the consequences of the spatial form, the fourth, creativity, is the reason for it. Cities are shaped to create non-local social networks for micro-economic purposes, local networks for socio-cultural purposes. This is why economic success is associated with non-local rather than local measures. And this may be what it means to say that cities exist to create contact.

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Chapter 6
Design Thinking as Principles for the Structure of Creative Cities

Andy Dong

Abstract Birds build nests, and bees build hives, and bowerbirds build bowers. Humans build villages, suburbs, urban metropolises, space stations, and virtual, online worlds we cannot actually live in but often spend more time in. We are not just the "wise" species—we are *homo designare*. We are the species that designs our world. We have a unique capability for design thinking, an open-ended capacity that enables us to create novel objects, environments, or situations by combining and recombining, and sometimes inventing, base elements into novel constellations. In this chapter, I present design principles for creative cities derived from a cognitive perspective on design thinking. To do so, I will build up a cognitive model of design thinking. I will then use this cognitive model to propose principles that we should apply to the design of creative cities.

6.1 Introduction

We are not the only animals who change the environment to suit ourselves. Beavers are a canonical example: they build dams because they require their burrows, or shelters, to have access points under water (Gurnell 1998). Intriguingly, beavers do not build only one type of dam, nor are dams built of any single type of material. As in humans, some animals work cooperatively to modify their environment. Termites as a collective build mounds of remarkable complexity and have been characterized as being "among the world's most sophisticated animal architects" (Turner 2010, p. 20). J. Scott Turner (this volume) describes the swarm cognition displayed by termites when they cooperate to build and maintain complex mounds, which regulate heat and gas exchange and thereby maintain homeostatic nest conditions. When birds and gorillas build nests or beavers dams or termites mounds, they are actively adapting the environment to their specific needs.

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Evolutionary biologists term the behavior of animals who actively modify their environment, and thereby influence the selection of genetic traits, *niche construction* (Day et al. 2003; Odling-Smee et al. 1996). In humans, we call this behavior design.

Unquestionably, humans have an exceptional capacity to design our world. Though there are some cognitive capacities that set humans apart from even our closest surviving animal relatives (see Suddendorf (2013) for a review) and we share many fundamental abilities with other animals, only humans have the necessary cognitive skills to design our world to suit our future needs (Suddendorf and Dong 2013). The most parsimonious answer to the question of why humans have an exceptional capacity to design our world is the relatively large size of our brains. It has also been put forth that there is a single, related answer to the question why it is that large cities seem to have a higher capability for knowledge creation and innovation: population size (Bettencourt et al. 2007a, b).

A question that evolutionary biologists continue to debate is *why* humans developed such a large brain. The *expensive tissue hypothesis* proposes that encephalization—the ratio of brain size to body mass—increased relative to the size of other metabolically expensive organs such as the liver, heart or kidneys as our diet improved in terms of food quality and ease of digestion (Aiello and Wheeler 1995). Since the dietary tract consumed less energy to digest food, more energy could be devoted to the growth of the most metabolically expensive organ: our brain. In contrast, the *social brain hypothesis* proposes that the need for large social groups drove the increase in encephalization (Dunbar 1998). When the groups became sufficiently large, increased brain capacity enabled language development (Aiello and Dunbar 1993). Whatever the ultimate cause may be, and there may be more than one, brain size is nonetheless a significant predictor of cognitive ability. It may turn out that it is not brain size per se that determines the cognitive abilities relevant to human achievement. Rather, our brain's internal structure, such as the number of neurons and neural pathways and the resulting relative sizes of important cognitive processing areas (Jensen 1998), or its internal functions, such as coordination functions (Kelso et al. 2013), determine cognitive abilities.

In his book *The Artificial Ape: How Technology Changed the Course of Human Evolution*, Taylor (2010) offers an alternative hypothesis. He claims that technology produced modern humans, rather than the other way around. Taylor explains that the invention of the sling, a device he believes is only a short conceptual leap from chimpanzees carrying their young on their backs, prolonged the human gestation period by allowing the skull to enlarge outside the womb. In other words, it was the sling—an early adaptive technology—that enabled us to grow larger brains. Hence—because technology shaped and influenced the selection of genetic traits for a larger brain—we are 'artificial apes'. The invention of the sling itself would not have required more than secondary representation, a cognitive skill documented in all great ape genera (Nielsen et al. 2005; Suddendorf and Whiten 2001). Secondary representation is the basis for imitation—such as humans copying the carrying of infants on our backs from chimpanzees—and means-end reasoning. Both are necessary to make the connection between carrying an infant and crafting a simple sling from available materials to suit that purpose. Given that humans share the cognitive skill of secondary representation with all great ape genera, the evolutionary origins of a mind capable of inventing a sling dates back at least 14 million years, long before the appearance of cities or even language.

Today, we continue to live in artificial worlds that have shaped our evolution (Taylor 2010). Cities are perhaps the most important artificial world that humans have developed. We have evolved brains that can design cities of increasingly sophisticated forms. It may never be possible for us to know how the design of our cities will influence the evolution of our brains or even which inventions and designs already had the greatest impacts on the evolution of our brains. However, could knowledge about the structure and function of a brain enabled with the capability to design our world provide useful principles for the design of cities? More precisely, given what we know about design thinking—the cognitive strategies and skills and forms of mental representations associated with designing objects, environments and situations—how should we design our cities to make us more creative? Whilst it is a long arc to draw, I would like to suggest that the cognitive strategies and skills that enable design thinking and the structural regularities underlying knowledge creation and innovation in cities (Bettencourt et al. 2007a, b) positively influence one another. That is, our complex brain enables us to build complex cities. Increasingly complex cities are specialized niches that, in the short term, provide environments for brains to maximize their potentiality and, in the long term, increase the likelihood of the selection of a set of genetically endowed traits favoring complex brains. Further, it is not simply a complex brain that is of interest to this reciprocal relationship. Rather, it is the design thinking mind—the mind that can design the world to suit our needs—because the design thinking mind is essential to the innovation cycles that prevent the stagnation of cities (Bettencourt et al. 2007a, b). I propose a working definition of design, as I have outlined elsewhere (Dong 2010), as the capacity to envision a nonexistent material world to a level of complexity that is not obvious based on the local material environment and then to reify that nonexistent world in material or symbolic semiotic form. The latter part of this definition accords with the idea that artifacts "reflect projections of intent from a mind into the external world" (Gowlett 2009). In other words, this definition of design requires that we can do more than rely on the perceived affordance of an existing object to, say, test the depth of water before crossing it, a behavior which has been observed in orangutans (Russon et al. 2010). Rather, we would gather up sticks and vines to build a raft and cross the water on it, building on our observation that sticks float on water, even though we may not understand the physics of buoyancy.

To address this hypothesis, I will build up a cognitive model of design thinking. Since the number of cognitive strategies and skills associated with design thinking will be expansively large, I will focus attention toward those cognitive strategies that are associated with productivity and high-quality design outcomes. I will also focus on the cognitive skills that humans possess to imagine new objects, environments, and situations (Dong et al. In Press). After describing this model, I touch upon social institutions and practices that build upon our biological capability to design (Dong et al. 2013). I conclude by describing the advantages cities provide and the implications of this model on principles for creative cities.

6.2 Cognitive Strategies and Skills for Design Thinking

Historically, design research focused attention on activities considered unique or essential to designing in relation to other human activities. For instance, the ‘object’ of design and its form and aesthetics (Whitfield 2005) figured centrally in design research from the start. Simon (1969) started the cognitive turn in design research by emphasizing the “forms of reasoning” associated with designing. He claimed that these forms of reasoning differed from forms of reasoning associated with the natural sciences. Since then, the cognitive design research paradigm (Visser 2006, 2009) has viewed design as a cognitive activity as opposed to a set of specific practices relevant to the object being designed. Goel and Pirolli (1992, pp. 395–396) characterize designing as a “quintessential cognitive task” and state, unequivocally, that: “Design is, therefore, fundamentally mental, representational, and a signature of human intelligence: Features that surely make it an important subject of study in cognitive science” (1992, pp. 395–396). Since this research paradigm considers that the thinking processes associated with design are independent of the object being designed, scholars in this area produce generic schemas (Gero 1990) and descriptions of the cognitive activities taking place during design. In addition, they claim a causal relation between particular cognitive strategies and forms of mental representations of designs and the productivity of the designer (Goldschmidt 1992). That is, while a number of cognitive strategies (e.g., brainstorming, trial-and-error, depth-first search) can be applied toward designing, only a subset of these is associated with high productivity and high-quality design outcomes. These cognitive strategies are observed across successful design cases and in a form that differs between highly experienced practitioners of design and novices. For example, in a study of mechanical engineering design, researchers found that expert design engineers used analogies to reason about the function and predicted behavior of a component, but this strategy was absent in novice engineers (Ahmed and Christensen 2009). *To date, cognitive design research has identified four key cognitive strategies associated with designing*: framing (Dorst 2011); abductive reasoning (Kolko 2010; Roozenburg 1993); analogical reasoning (Ball et al. 2004; Visser 1996); and mental simulation (Ball and Christensen 2009; Christensen and Schunn 2009). Identifying productive cognitive strategies forms the research basis of design thinking[1] as well as my cognitive perspective on it.

[1]Some authors use the term ‘designerly ways of knowing’ (Cross 2006) or ‘designerly thinking’ (Johansson-Sköldberg et al. 2013) to distinguish between this cognitive perspective on design thinking and the more practice-based or processual view on design thinking which is primarily used in the literature on management (Brown 2008). For the purposes of this article, I will use the term design thinking with reference to the cognitive design research paradigm.

In turn, the cognitive strategies of design thinking rest on a set of fundamental cognitive skills that are part of the general texture of cognition. These may have been adapted (or evolved specifically) to support our ability to shape our environment to suit us; having the ability to shape the world to suit our survival needs would have maximized humans' chances for reproduction in comparison to other species.

Whereas research on the key cognitive strategies in design thinking is both rich and convergent, the foundational cognitive skills associated with design thinking remain less understood. One approach to identify the fundamental cognitive skills that underlie human design thinking is to look to other species because we are not the only great ape, or even species, to behave creatively and innovate (Reader and Laland 2003). The production of novel and useful artifacts has been recorded for our closest relatives, the great apes: tool making by chimpanzees (McGrew and Collins 1985; Schick et al. 1999); novel methods to obtain food, make nests for sleeping and resting, and appropriate and modify objects for comfort and protection (such as leaf umbrellas) by orangutans (van Schaik et al. 2006); and, dating back at least 4,300 years, the use of stone products of thrusting percussion to crack open nuts by chimpanzees (Mercader et al. 2007). Imaginative capacities which we share with closely related species are likely to be homologous: that is, inherited from a common ancestor (Suddendorf and Dong 2013). Thus, it is more parsimonious to assume that this capacity evolved only once—in our common ancestor—than to assume that it evolved on independent occasions. The cognitive (and neurological) mechanisms underlying homologous capacities in related species are likely to be very similar.

Creative outcomes can arise through a variety of activities. Not all of these activities require a mental representation of either the external world or of processes acting on the world to achieve a desired outcome, which are distinguishing cognitive elements of design thinking. Nonetheless, there is sufficient evidence of animals behaving creatively and producing innovations in ways not attributable to mimicry or accidental discovery to suggest incipient design thinking cognitive skills in the great apes.

Based upon an analysis of recent literature in comparative psychology and early childhood cognition, Dong, Collier-Baker, and Suddendorf (In Press) identify three candidate cognitive skills: *recursion*, *representation*, and *curiosity* as fundamental to the conceptual system of design thinking, that is, the system that gives us the mental ability to produce a knowledge structure about an object, environment or situation. Recursion allows us to combine and recombine basic elements into novel mental scenarios. As such, it plays a direct role in design by providing us with the capacity to generate an infinite range of artifacts from a finite set of physical elements and construction operations. Recursion also enables nearly unlimited flexibility and conceptual possibilities in design processes. One characterization of the design process is that designers respond to a design situation by proposing 'primary generators' (Darke 1979). These primary generators are not design concepts; rather, they are a small set of objectives used to give rise to an expansion or projection of conceptual possibilities. Generating new conceptual possibilities from primary generators requires the cognitive skill of recursion to derive additional propositions based on the initial proposition in a process that is "spiral and iterative" (Darke 1979). To date, recursion has not been definitively observed in any nonhuman species, and the current consensus is that it is unique to humans (Corballis 2007; van Heijningen et al. 2009).

The second skill is representation. Following the model of Perner (1991), the cognitive strategy of framing relies on a capacity to represent design situations in ways that have a direct semantic relation to the world (primary representation), in ways that model the world through a particular abstraction such as function (secondary representation), and then interpreting and evaluating the way of representing —a reflection which requires an understanding that the representation itself can be represented in turn (meta-representation). Of these three representational skills, only meta-representation has not been observed in non-humans, likely to due to its reliance on the cognitive skill of recursion. Meta-representation is at the heart of design because it allows us to compare alternatives and to consider the validity of various representational relations such as, for example, whether to frame the design solution to our interaction with computers as 'menus' or 'windows'. Mental simulation rests on recursion and representation; recursion enables us to string together different scenarios into causal sequences (narratives) and, when combined with meta-representation, entertain multiple explanations of that narrative.

Finally, curiosity provides the "thirst" that drives us to produce artifacts with an exuberant range of variation. It has been argued that cultural preference for novelty can drive variation (Martindale 1990). Since culture is often defined by variations in patterns of behavior in the absence of plausible environmental explanations, an innate capability for representational variation must logically precede culture. Others have argued that sexual selection would have led to a reproductive advantage for those with 'creative' skills that could make things that were both novel and useful (Kohn and Mithen 1999; Miller 2001). Their explanation implies that females are the 'choosy' sex, and that males must display behaviors that females prefer, giving creative males a reproductive advantage. This advantage generated a selection for brain functions that facilitate creativity, leading to runaway selection for creativity and hence increasing variety in cultural artifacts and practices over time. Thus, while social factors are recognized as an important extrinsic factor for novelty production, designing requires a cognitive capacity for novelty that cannot be pre-determined by social or environmental factors alone.

Curiosity may be a predisposition of the mind owing to the architecture of the brain. One of the most important architectural (anatomical) differences between the human and primate brains and those of many other species is that, in our brain, conception is not directly connected to sensation. Our cerebral cortex lacks interconnections linking the unimodal areas that serve our different senses. Sensory information undergoes extensive associative elaboration. The large number of alternative trajectories and transmodal pathways through the brain activated as sensation is transformed into cognition means that the same sensory stimulus can potentially elicit numerous alternative representations (Mesulam 1998). The consequence of this behavior permeates all aspects of cognition and underlies the

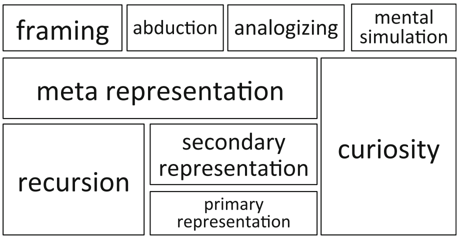

Fig. 6.1 Cognitive skills enabling design thinking

uniquely human aptitude for discovering multiple solutions to similar problems. Combined with our unique ability for episodic foresight (Hudson et al. 2011) or mental time travel (Suddendorf et al. 2009; Suddendorf and Corballis 2007, Portugali, this volume), curiosity galvanizes us to propose alternative possible futures. It is worth our while to seek synthetic knowledge about what the future might be like, so that we can design with the future in mind. Designers then employ the cognitive strategy of abduction to propose a hypothesis or best explanation for the most convincing versions of the future. Abduction is a cognitive strategy employed while designing to make sense of complex data about the world; it is necessary to prune and filter new alternatives spurred through curiosity (Kolko 2010). Curiosity, the cognitive capacity for novelty, would have been crucial as a primary motivator in the mental activation of alternative representations that gave novelty and utility some selective advantage.

Figure 6.1 summarizes the cognitive perspective on design thinking presented above. The key cognitive strategies—framing, abduction, analogizing and mental simulation—are supported by the cognitive skills of recursion, representation and curiosity. Building on this model, I return to the issue of creative cities in light of our aim of building design thinking minds.

6.3 Cities and Design Capabilities

Whether researchers use the term design, innovation or creativity, they all hark back to a common reference: the successful creation and exploitation of ideas. In economics and development studies, the focus is on economic and social policy promoting innovation. Economists and policy-makers tend to agree that innovation is the fundamental outcome of a creative economy, and that the creative economy is, in turn, a core generator of economic activity. Underlying this recognition is an assumed capacity to deliver innovation but also a popular appreciation, demand for and consumption of innovative products and services. Spurred by discourse on the relation between design, innovation and economic policy (Florida 2002; Landry 2000), local governments in Europe, North America, and Australia have been formulating policy to encourage centers of creative activities to underpin design industries (Malecki 2007). According to the empirical analysis of the economies of several North American cities by Florida (2002), policy makers simply need to invest in the right mix of technology, tolerance and talent. Various cities around the world have taken heed of the creative cities policy recommendations made by Florida (2002) and Landry (2000). Cities in the UK such as Liverpool, Sheffield, Birmingham, Newcastle and Belfast have ‘creative quarters’. In inner suburban Brisbane, Australia we find a conceptually similar ‘creative industries precinct’. Developing countries also see design as part of and a precursor to human development; design and development policies are often based on an ethic of inclusiveness, making them part of an endeavor of social justice and, in the words of Gui Bonsiepe (2006), not a “tool for domination”. In developing countries, however, development is not always democratic (Drydyk 2005) and foreign direct investment in skills, like those promoted by Florida and Landry, tend to favor highly skilled countries (Velde and Xenogiani 2007); the question of what type of policies favor creativity in cities—worldwide—while promoting human development is far from resolved.

I propose the model shown in Fig. 6.1 *as a starting point for thinking about* structural regularities underlying knowledge creation and innovation in cities. This provisional framework formulates the core human cognitive skills and strategies that allow a person to design. Given the framework, one pathway to enhancing design-oriented minds is through social and political institutions. I have proposed a Design Capability Set (Dong 2008; Dong et al. 2013) to assess the extent to which social policy and institutions contribute to—or, conversely, detract from—the expression and enjoyment of the cognitive capabilities that underlie design. The six dimensions of the design capability set and their examples are:

- **Abstraction**—the capability to build up and sustain valuable cultural resources that provide the raw material for creative activities such as design; examples include social institutions and practices that document and preserve culture such as the Smithsonian, and public and private financial support to the arts and other cultural initiatives.
- **Authority**—the capability to exert a positive or negative obligation on government to design a world that they value; an example is the California voter initiative process, which has been applied to compel governments to provide particular forms of public infrastructure and amenities.
- **Evaluation**—the capability to validate design solutions put forward, both during the design process and when the design work has been completed; one example is citizen juries that judge submissions to design competitions for public buildings, another is community consultation in urban planning.
- **Information**—the public entitlement to information that is authoritative, complete and truthful; examples include the *Ralph M. Brown Act* in the state of California—commonly known as Sunshine Laws—which mandate public agency meetings be made open to the public—and freedom of information acts
- **Knowledge**—the capability to have general knowledge of the practice of design; examples of knowledge capability enhancing institutions include museums of design, tool-lending libraries and ‘do-it-yourself’ workshops such as the Maker Faire.

- **Participation**—the capability to set conditions for meaningful citizen participation; an example is "21st Century Town Meetings" wherein many thousands of citizens collaboratively frame complex problems and produce working principles—or recommendations—for action (Lukensmeyer and Brigham 2002).

The design capability set is one way to link the socio-political environment with cognitive strategies and skills associated with design thinking. How could urban design itself contribute to and influence more capable design thinking minds? As a first step toward addressing this question, I describe three ways that cities could amplify the development of design thinking: establish a broad basis for analogical reasoning; display complex situations for inhabitants to frame into meaning; and maintain a repository of cumulative cultural knowledge that induces mental simulation to reason about the past and future design iterations. This discussion leads to a set of design principles for the structure of creative cities.

One obvious way that cities can support design thinking is by providing stimuli for creative thought, stimuli that become sources for analogies. In analogical reasoning, designers apply similar properties or features of a prior object to the current design problem. Analogies have figured prominently as inspirations for design, not only in an anthropometric sense wherein a building is designed to 'look like' a natural object, but also to exert a framework over subsequent sequences of problem formulation, interpretation and solution assessment (Rowe 1982). The problem with using analogies for creative design is that the relevant reference knowledge base is not necessarily available. That is, the sources of analogies are not necessarily shared or equally available for one reason or another; one might not have had the opportunity to be exposed to a rich array of examples. A study by Strickfaden and colleagues described the effect of students' opportunities for social and cultural activities prior to their tertiary architecture education on their design performance. They claim that design students acquire a cultural medium consisting of places, objects, events, and architecture through their experiences, such as by traveling to various cities around the world or through everyday experiences. Students who had the opportunity to acquire a broader and richer cultural medium could draw upon it as the material for the production of new design concepts whereas those with a limited cultural medium tended to struggle. Design educators could assist students to "search within themselves and in their environment to learn about the things they are designing" (Strickfaden et al. 2006, p. 98), but students must already possess or have access to the development of a cultural medium for the educators to be effective. Cities that amplify the opportunities for individuals to acquire a rich cultural medium through its design thereby give an advantage to individuals within these cities.

The effects of this advantage are broadly reported. The robustness of creative industries is a key indicator of the design culture of a broad community and has been strongly correlated with economic vitality (Jayne 2005). Likewise, arts and culture vitality is correlated with the resurgence of economic vitality and cultural identity (Aksoy and Robins 1997). In the United States, the Urban Institute's study of cultural vitality (Jackson et al. 2006) and the Social Impact of the Arts Project

(SIAP) at the University of Pennsylvania School of Social Policy and Practice are unequivocal in their findings that the provision of public arts institutions and urban cultural vitality are strongly correlated to social cohesion and quality of life. Further, the Urban Institute recognizes the importance of both the formal arts and culture sector—such as museums, operas and commercial creative activities—and the informal sector of amateur and opportunistic creative activities that result in the creation of skills for the conceptualization, realization, and diffusion of cultural artifacts and events. These informal cultural activities can progress onto established programs, such as the Edinburgh Festival Fringe growing from a group of theaters performing on the sidelines of the Edinburgh International Festival into a cultural event in its own right. The development of skills for cultural invention makes artistic cultural vitality a capability-building dimension for design.

The importance of out-of-domain analogical reasoning as the basis for creative problem formulation and solving (Christensen and Schunn 2007; Kalogerakis et al. 2010; Tseng et al. 2008) suggests two principles for creative cities. The first is that mixed-use schemes should be preferred. Precincts concentrating a specific industry would be eschewed in favor of more diverse industries, as in biotechnology next to digital media or aerospace manufacturing next to architectural design, to permit cross-fertilization of ideas. Second, it suggests that urban designers and planners should design schemes that allow for coincidental or ambiguously defined mixtures to emerge within otherwise structured physical, socio-economic encounters. Such schemes would provide opportunities to stimulate new creative ideas by analogical transfer of ideas from another domain. The curious, novelty-seeking brain—enabled by transmodal pathways in the brain—further suggests a need for multi-scale, multi-modal transport options that can, literally, transport people through the city following more than one path. Not only could multiple paths through a city promote redundancy in the transport network, it also enables inhabitants to encounter random conceptual links, or, in other words, random analogical stimuli. This creative city principle is consonant with Bill Hiller's suggestion that the city-creating process is based on multi-scale connections (Hillier this volume). Hiller argues that there is a social advantage associated with bigger, more spatially dispersed and hybrid networks. Multi-scale interconnections throughout this network make it possible to grow various conceptual groups and for someone to meet someone else with a random conceptual link. Such is the basis of familiar strangers (Sun et al. 2013), unintentional, passive encounters with other individuals through regular, everyday activities that can be the precursor to the development of social communities.

The second type of stimuli that cities provide exercises the cognitive strategies of framing and abduction. These are the complex stimuli that force us to make sense of unfamiliar situations. Krippendorff (1989, p. 12) explains this type of stimulus in the following way: "Seeing something in a store as a chair requires imagining its use at home or in an office, a context that may or may not be realized in practice." In other words, we frame stimuli to extract patterns and meaning. We might then introduce a hypothesis through abductive reasoning to logically explain the validity of the frame. We might use metaphors to interpret an object or situation by reference to another object or situation, such as in describing an object as 'warm' in the sense of being comfortable, inviting, and cozy. Empirical research has identified that designers routinely use metaphors to frame (Hey et al. 2008) and structure (Casakin 2007) ill-defined problems in a more familiar way. As cities become increasingly complex and varied, we will seek statistical regularities (commonalities between chairs, stools, benches, and other forms of seating or houses, office blocks, skyscrapers and other types of buildings) and produce models (what chairs look like; what modernist office buildings look like), storing them in our memory. The number and information content of the categories of buildings we conceptualize increases as we perceive more examples, until we eventually produce mental models of buildings (Haken and Portugali 2003). The logical consequence of these observations is the principle that cities should provide more typological examples and more possibilities for design thinking minds to generate frames of increasing diversity and richness of information content. A diversity of unique stimuli affords the creation of many plausible alternative framings of observed reality.

Finally, cities store large repositories of cumulative cultural knowledge. The contemporary city is, as Mumford (1961) described, a "container of culture". Cumulative cultural evolution refers to the transmission and accumulation of ideas, skills, traditions and other cultural artifacts such that each subsequent generation benefits from the advances made in the prior generations. This accumulation results in cultural artifacts of increasing complexity and sophistication. Having access to information from various designed artifacts through history constitutes knowledge in context. This contextualized understanding of the design inherent in everyday objects allows designers to make use of past experiences that have become embedded in everyday material culture (Demian and Fruchter 2006). For instance, we make enhancements to objects to suit the exigencies of the current situation and over time these objects may become increasingly useful, as their original design is updated by current contextual design interventions on them; designed artifacts accumulate modifications from generation to generation with each subsequent generation benefiting from the "ratchet effect" of cumulative cultural evolution (Tomasello 1999). Cumulative cultural evolution depends upon innovation, itself relying on imagination, and transmission via either imitation or instruction. Social—rather than genetic—transmission of adaptive information has enabled us to more rapidly change and control our environment. This cumulative ratcheting effect both relies upon and demands an ability for mental simulation: to make use of it, we must mentally construct the series of social and technical inputs that led to the introduction of a designed artifact and to plan the series of steps that allow us to create an object that will serve an anticipated future purpose. Design always entails imagining a future object and a future world that does not yet exist. The problem is figuring out possible future worlds. One of the most productive uses of mental simulations is to imagine cities that do not currently exist and how they might benefit (or injure) us. The *preservation* and *reuse of buildings would therefore be preferred over their demolition, as historic buildings not only preserve the history of place (and as such past contexts); they also embody cumulative cultural knowledge that can inform and enhance future design iterations*.

6.4 Concluding Remarks

In this chapter, I proposed a set of principles for the design of cities. The structure of cities should:

1. Facilitate opportunities for opportunistic encounters to encourage out-of-domain analogical transfer of ideas
2. Cultivate complexity in form to induce the generation of frames of increasing number and novelty about the meaning of city forms
3. Embody cumulative cultural knowledge to inform and enhance future design iterations

The principles are based on a cognitive perspective on design thinking. The organization of cities has followed numerous theories with focus as disparate as economy, geometry, technology, and finance (Hall 1988). Cognitive design research may offer new ways of conceptualizing the organizing principles for the spatial organization of cities. Just as urban planning has started to respond to issues surrounding public health as a set of organizing principles for the spatial layout of cities (Saelens et al. 2003), perhaps cities can promote smarter and creative minds by responding to concepts from design thinking.

The neural resources of the human brain and the intellectual resources of cities may share more mechanisms for creativity and innovation than scale—a common factor of both urban agglomerations and computing power. Cities are specialized niches that we have created; they can promote our creativity by design rather than hinder it. Our creative brains have been wired to design increasingly sophisticated cities. Perhaps we should wire our cities to produce increasingly creative minds.

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Part II
On Termites, Rats, Other Animals and Cities

Chapter 7
Swarm Cognition and Swarm Construction: Lessons from a Social Insect Master Builder

Scott Turner

Abstract Termites of the genus *Macrotermes* are renowned for the large mounds they construct. This structure, which is built above the colony's subterranean nest, is one of the most remarkable animal-built structures on the planet—remarkable both for its size (up to 11 m tall), and for its complex function. At one level, the mound is a superorganismal organ of physiology: the colony's lung. It captures turbulent wind energy to power respiratory gas exchange. At the same time, the mound's respiratory function is embedded in a larger matrix of the colony's overall physiological function, integrated with other functions such as moisture balance, waste disposal and digestion. Thus, like conventional organs of physiology such as lungs, hearts, guts and skin, the colony's "lung" is an expression of a broader purpose: colony level homeostasis. Homeostasis requires both the ability to appraise environments and to do work to change them: to adapt the environment to the organism, turning a well-known trope on its head. As it does in conventional organ systems and organisms, the superorganismal homeostasis of the termite colony betokens a complex cognitive system at work. In my contribution, I outline our current understanding of the system of "swarm cognition" among these termites and how this integrates with the operational rules that govern "swarm construction": the cooperative effort to build and maintain the mound. I go on to consider what lessons, if any, this offers the discipline of urban planning. To wit: should there really be such a thing? The emergence of the complex and integrated function of the termite colony is an expression of a broadly-based, "bottom-up" cognitive system: it proceeds without any "plan" directing it. Understanding cities and other urban systems as an expression of the "cognitive swarm" of their inhabitants, one must ask to what extent the imposition of a "plan" by architects and urban designers can lead to integrated, well-functioning and well-designed urban systems. Should architects and urban planners be "planners" per se, imposing their vision on cities and the people that live within them, or should they be "implementers" of the organic development that will arise as an expression of the "swarm cognition" of the city's inhabitants?

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7.1 Introduction

This conference is devoted to a radical question: What lessons, if any, can we learn from nature about constructing urban environments? I want to say at the outset that I am neither an urban planner nor an architect or an engineer, so what I have to say should probably be taken with a rather large grain of salt. What I am is a biologist who studies social insects and adaptation. What I have to say *may* be germane because the insects I study construct "cities" of their own, after a fashion. These insect societies are remarkably well functioning, naturally prompting me to reflect on what lessons, if any, these insect assemblages may have to tell us about the design and engineering of the large assemblages of creatures—humans, primarily—that inhabit urban environments. This is currently an acute problem, and is likely to become more so in the future. At present, roughly half of the world's human population lives in cities and suburbs, and this proportion is likely to increase rapidly, especially in the world's developing countries, which are in the midst of a long-term net migration of their populations from rural to urban settings. It is projected that nearly all the projected global human population growth will occur in cities (Cohen 2006). How we construct and manage our increasingly large (and complex) urban environments is a rather urgent matter to get right.

Urban planners and architects presumably look to insect societies because they believe that living nature may have something important to tell us about how we build and manage our own environments: the hopeful promise of biomimicry (Benyus 1997; Gruber 2008; Odling-Smee and Turner 2011; Tsui 1999). As a biologist, I look upon this growing trend with a mixture of hopefulness and trepidation (Turner and Soar 2008). The hope comes from the same motivation that drives the emergence of biomimicry: Nature is, indeed, full of marvelous designs, contrivances, and processes. It is simply true, to the point of triviality, that we really could learn much from nature about how we organize our lives. The trepidation I feel is a little more complicated. The current fashion for biomimicry is driven by a remarkable idealism, which has a mixed record in improving our lives, particularly when that idealism is wielded by individuals, organizations and governments that have power over others. Given the seemingly inexorable trends toward future urbanization, and the sheer number of people that will be involved, it's vital that we understand precisely just what lessons living nature can teach us, and what lessons it cannot.

7.2 A Natural Urban Environment

People build cities, suburbs and towns, because we are social animals. We assemble into communities, specialize, trade and build wealth. To do any, or all, of those things requires an infrastructure that facilitates them. The core question is how this infrastructure comes into being.

Humans are not the only social animals in the world. Insects provide a wealth of spectacular examples of living societies (Hölldobler and Wilson 1990; Hölldobler and Wilson 2009; Wilson 1971). Among insects, the social habit is found in two classes: the *Hymenoptera*, that comprises the bees, ants and wasps; and the *Isoptera*, or termites. What makes the social habit of particular interest is the remarkably different evolutionary histories of these two insect classes. The termites arose near the end of the so-called 'age of the amphibians,' the Paleozoic era, and the beginning of the 'age of reptiles,' the Mesozoic era. Termites are monophyletic, that is to say, all of the roughly 4,000 species of termites that exist today can trace their origins to a single root lineage. This means that the termites' social habit traces its origins back as far as the insect class. The Hymenoptera are also monophyletic, arising from an ancestral stock of wasps that proliferated into the two groups of advanced social insects that exist today: the bees and ants. The evolution of the social habit among them is more complicated. Among the bees and ants, the social habit has arisen independently among at least five lineages of these insects.

Despite these multiple independent origins of the social habit, all of the social insects, whether they be termites or any of the roughly 32,000 species of bees and ants, have remarkably similar societies. They organize into colonies, each with a fecund queen and king that are the parents of hordes of sterile offspring—the workers. The king and queen invariably have much longer life expectancies than the workers, and the reproduction of the king and queen is devoted entirely to the production of these sterile offspring. Social insect colonies must reproduce as well. Colony reproduction is typically through reproductive proxies that arise as reproductively competent siblings of the sterile workers. Reproductive competence is under the control of the sterile siblings.

This similarity of social organization of these two insect classes, despite their very different evolutionary origins, is an example of a more general phenomenon known as evolutionary convergence. We currently have no general theory for how evolutionary convergence works (Conway Morris 2008; Ruse 2008). I would argue that this is because we do not currently have a general theory for how evolution works (Turner 2013a). We can, however, gain some insight into the form of insect societies by looking to the mechanisms through which they bring themselves into being—a problem akin to exploring how cities emerge in human societies. For example, a feature common to social insects is the collective construction of habitats in which the colonies live. Bees, for example, construct hives in the hollows of trees and in excavated cavities underground, a habit which beekeepers have exploited to human benefit (Winston 1991). Ants construct remarkable systems of burrows, nests and galleries; termites do likewise. Some of these structures are simple, but can be elaborated into structures of breathtaking complexity and scale. The leaf cutter ants, for example, construct enormous networks of underground passageways, which include nests for eggs, galleries for processing and cultivating food, massive garbage dumps and systems of towers that aid in ventilating and renewing the atmosphere inside the structure (Kleineidam et al. 2007).

The insects which I study, the family of termites known as *Macrotermitinae*, build structures of similar scale and complexity. These termites assemble into immense colonies of up to 2 million sterile individuals, all of them the offspring of a single fertile female: the Queen. The workers occupy a consolidated subterranean nest that is about 2 m in diameter. From this base, the colony develops an impressive infrastructure for exploiting a foraging territory that is roughly two hectares in extent (Dangerfield and Schuurman 2000; Inoue et al. 2001). At any time, roughly a third of the colony's workers are out of the nest, foraging and gathering about a ton of food per year (LePage 1981), mostly dry grass, but also bark from trees, pats of animal dung, fallen twigs and other woody materials. The workers patrol their territory through a network of subterranean foraging tunnels that radiate as far as 70 m from the nest. The foragers bring the gathered material back to the nest where another class of termites takes the forage and processes it through a massive self-constructed composting operation. The gathered forage is macerated, moistened and inoculated with a fungus, which decomposes difficult-to-digest woody forage into an enriched diet of fiber, simpler sugars, various fungus-derived vitamins and other nutrients (Batra and Batra 1979; Darlington 1994a, b; Leuthold et al. 1989; Rouland et al. 1988; Wood and Thomas 1989).

This complex food economy requires additional infrastructure to make it work. Taken together, the fungal and insect inhabitants of the colony consume oxygen and produce carbon dioxide at a rate similar to that of a large mammal sized somewhere between a goat and a cow (Darlington et al. 1997). This presents the termite colony with a physiological problem. How can oxygen from the atmosphere be delivered to its point of consumption—the termites and fungus gardens of the nest—at a sufficient rate? A similar, if converse, question may be asked about the prodigious production of carbon dioxide gas, which must be conveyed the opposite direction from the oxygen: from the nest to the atmosphere. Animals face the same problem in conveying the respiratory gases between the atmosphere and the body's innumerable cells. They meet this physiological problem with a gas exchange infrastructure, the lungs, and the distribution systems of the heart and circulation. The termite colony meets the problem by constructing a gas exchange infrastructure of its own: A massive mound built from several tons of soil, usually 2–3 m in height, serves as the colony's wind-driven lung (Turner 2005; Turner 2006a).

The mound can serve as the colony's lung because it is built to do so, and its function depends upon a sophisticated architecture. The mound powers gas exchange by capturing energy from turbulent winds, which it does through the mound's porous surface. The mound's porosity is a secondary effect of mound building, but integral to its function. Termites build their mound by depositing moist soil on the mound's surface (Turner 2011). Access to the mound surface is through a termite-constructed reticulum, the egress complex, which lies just below the surface. Separating the air spaces of the egress complex from the atmosphere is a thin layer of friable soil, sometimes just a single layer of glued together sand grains, which makes for the mound's outer porous covering. Internally, the egress complex opens up into a reticulum of larger tunnels that penetrates into the nest interior, and envelops the nest in a subsurface reticulum that merges into the radiating network of foraging tunnels.

For many years, it was thought the mound's internal network of tunnels conveyed large scale bulk flows of air through the nest. These notions are derived from an influential paper published in 1961 by the Swiss entomologist Martin Lüscher, who proposed that waste heat produced by the nest, at a rate of roughly 100 W, drove a large-scale circulation of air between the nest and mound surface (Lüscher 1961). A variant on this theme looks to Venturi effects to draw fresh air into the nest and out through large open chimneys above the nest (Weir 1973). Despite these models' prominent presence in both the termite literature and the literature on biomimetic architecture, we now know them to be mostly wrong. I do not wish to labor the point here, simply to state that the mound captures wind energy in a totally innovative fashion, and that this function derives from a collectively-constructed infrastructure of remarkable sophistication.

Managing the colony's water needs also involves some impressive collective engineering (Turner 2006b; Turner et al. 2006). The moisture of the nest is regulated tightly year-round at a prevalent humidity of about 80 % RH. Termites themselves are generally not well-equipped physiologically to handle water deprivation (Abushama 1974), but in the case of the *Macrotermes* colony, the tight regulation of nest humidity benefits their cultivated fungi. If conditions are too dry, the fungi go dormant, and production of their composted diet declines. If conditions are too wet, other species of wood-rotting fungi take over the fungus combs, outcompeting the termites' cultivated species. The consequence of either is dietary deprivation for the termites (Batra 1971; Darlington 1994a, b; Rohrmann 1978; Thomas 1987).

Macrotermes colonies are typically found in the tropical savanna, an environment marked by extreme variation in the availability of water. During the dry winters, the soil and atmosphere become very dry, while the tropical savanna's wet summers are marked by periodic episodes of torrential rainfall. Add to this an El Niño-driven cycle of multiple-year droughts interspersed with multiple-year wet periods, and the colonies' water balance challenges become evident.

The *Macrotermes* colony overcomes these challenges by collective hydrological engineering (Elkins et al. 1986; Konaté et al. 1999; Lobry de Bruyn and Conacher 1990; Sieber and Kokwaro 1982; Turner 2006b; Watson 1969; West 1970). During dry conditions, worker termites mine liquid water from deep reservoirs within the soil. These efforts are impressive: Anecdotal reports from the mining literature show that termites can tunnel down as far as 100 m to find water and bring it back to the nest (West 1970). Such deep mining for water may be an extreme example. Most of the water mined by termites is likely to come from perched water tables a few meters below the surface that develop from biogenic deposition of calcrete nodules in the soil. These nodules grow together and fuse into a cobbled impermeable layer that can store substantial quantities of the water that percolates into the soil from the torrential rains in summer. This calcrete layer appears to be molded to form a basin below the nest that can collect water from a substantial area surrounding the nest (Boyer 1973; Boyer 1975a, b). During the winter, termites can access this water and transport it into the nest to offset the colony's considerable loss of water to the surrounding soil and atmosphere.

During the wet summers, termites have the opposite water balance problem. Water from the torrential downpours can percolate deeply into the soil, then overload the nest with excess water (Turner 2006b; Turner et al. 2006). In summer, the physiological challenge for the colony is to export this excess water. The workers do this by transporting it upwards into the mound in the form of wet soil. This is the principal driver for mound building. Termites transport as much as 250 kg of soil up into the mound each year, mostly in the rainy season, carrying with that soil a load of roughly 750 kg of water annually. This wet soil is deposited on the mound surface. We know this is a regulated process, because increasing the amount of water percolating into the soil surrounding the nest increases the upward transport of soil into the mound (Turner 2011).

To further balance the water in the colony, the termites construct a reservoir system within their nest, to clamp nest humidity and tide the colony over short-term fluctuations in environmental moisture. This reservoir resides in the fungus combs, which contain within them roughly 50 L of liquid water. This water is metered to and from the nest environment by the fungi. When humidity falls below 80 % RH, water evaporates from the fungus combs, while the fungi absorb water vapor when the humidity of the surrounding air rises above 80 % RH. The end result is a local nest humidity that is clamped at 80 % RH. The termites also top up these reservoirs with liquid water when they add fresh macerated forage to the fungus comb.

The *Macrotermes* colony shows many similarities to our own constructed urban environments: There are specialized sets of workers that maintain public water and sanitation infrastructure, there is an infrastructure of housing, streets and traffic control, and there are built devices that manage and mobilize power to do maintenance work, such as waterworks to feed water into the city as needed and a drainage system to manage the excess.

7.3 Urban Planning of the Termite City

Like a human city, the termite colony is a constructed environment that provides both habitation and the associated community infrastructure to support the comfort and sustenance of the inhabitants. Maintaining a human city typically involves a kind of top-down management structure that places government in the role of principal planner. Here is where the comparison of our cities with the termite "city" begins to break down.

The social insect colony was long thought to be "governed" in a similar top-down fashion: Aristotle conceived of the drone as the bee colony's "king." This conception changed in the 17th century with Samuel Butler's *The Feminine Monarchie,* which assigned rule to the queen (Wilson 1971). In fact, the relation between a social insect colony's primary reproductives (the "king" and queen) and their innumerable sterile offspring is complex, reflecting a markedly different kind of politics.

Among the *Macrotermitines*, the queen is little more than the reproductive slave of her offspring. She spends her life enclosed in a special chamber, the queen cell, deep within the nest. The termite workers bring her food and carry away her eggs, about 26,000 per day, to be nurtured and hatched elsewhere in the colony. The principal effect of the queen on the workers is to secrete a pheromone that suppresses her offsprings' reproductive ambitions (Bruinsma 1979; Yamamoto and Matsuura 2011). Nevertheless, her offspring manage the colony's reproduction through a kind of annual orgasm known as a mating swarm. The workers cultivate a few thousand of their siblings each year as fertile reproductive proxies (Batra 1971; Darlington 1986; Neoh and Lee 2009). Unlike the sterile workers, these individuals, called *alates*, develop with functional gonads, wings and eyes. Each annual crop of *alates* is released as a swarm from the colony at the beginning of the rainy season. These fly, mate and initiate nests of their own. Nearly all die as victims of predation, exposure or starvation.

Despite the numerous functional analogies that can be drawn between termite "cities" and our own urban environments, there is no analogy to be drawn between, say, the mayor of a city and the termite Queen. The queen plays virtually no role in the ongoing work of developing and maintaining the termite city. This is virtually the sole purview of the colony's large population of sterile workers, who "do it for themselves." Nor does the termite colony have anything resembling an urban planning board, or even a plan. Yet the termite colony functions impressively well. How do they pull it off?

7.4 Swarm Cognition in Mound Repair

The simple answer to this question is that we don't fully know. The answer that is emerging dimly is that this is a phenomenon of collective cognition. We can gain more clues into this by examining how termites respond to damage to the mound.

Drilling a hole in the side of a mound initiates an impressive repair project (Turner 2011). Within about 10 min of the damage being inflicted, groups of termites appear at the site of damage, and begin to repair the breach. Within a couple of hours, the hole in the mound has been sealed with a rough soil plug. This is the part of the repair project that is visible from the outside, but within the mound, the process continues. The plug extends several centimeters into the hole, as a tight network of tunnels called the "spongy build." The termites will continue to work the spongy build for a few days, gradually backfilling the plug. Eventually, when the plug is judged to be solid enough, the termites retreat to the nest and resume their normal activities. That is still not the end of the process, however. The plug is textured and shaped very differently from the broad, smooth interior tunnel that existed prior to the breach. This rough patch impedes air-flow within the tunnel, compromising the mound's function. For the mound to return to full functionality, the plug and spongy build must be dismantled, and the internal passageways must be restored to their original texture and caliber. This process can take months, even years: longer by far than the typical lifespan of a worker termite.

We've been trying to understand this process, because it raises a number of interesting questions. For example, very few termites are typically found in the mound at any one time. How, then, do the termites in the nest know there's been damage to the mound, at a point that can be several meters removed from the daily life of the colony? Once they are informed there has been damage, how do the blind and rather "stupid" termites know where to go to repair the damage? Once they have commenced repair, how do they know when the repair job is actually done? Finally, how does the repair project continue over the lifespans of several generations of termites?

What we have found is that the process of mound repair, and by extension the origin of the mound itself, is largely a cognitive phenomenon operating at multiple scales of organization (Turner 2011). Each worker is a cognitive entity, capable of sensing its local environment and responding to it. Workers can signal their cognitive perceptions to fellow workers through chemical and tactile communication, either directly or using various information proxies. These can spread widely through the mound itself, but can also be inscribed in structural memories that convey information across many generations of workers. The colony itself thus acts as a cognitive entity of sorts, conferring upon it a sort of super-individuality (Turner 2013b).

Mound repair unfolds in three roughly overlapping phases. The first phase is recruitment. Nest workers are informed that damage to the mound has occurred, and enter the mound to begin repair. Cognitively, termites are very attentive to changes in their local environments, but are largely indifferent to their environment as long as it is steady. Worker termites will, for example, labor assiduously under local concentrations of carbon dioxide that range from atmospheric (about 0.04 %) up to 5 %. If concentration changes abruptly, however, such as a sudden change of CO_2 concentration from 1 to 2 %, the termites become agitated and alarmed. They can also spread their alarm vicariously, informing termites that might not have experienced the change of CO_2 themselves of it, and imparting their sense of alarm.

This sensitivity to abrupt change in conditions is how termites in the nest are informed of damage to the far-away (for them) mound. The intact mound acts as a filter of the changing energy in turbulent winds, and this filtering action ensures that the normal nest environment is relatively still and steady compared to the constantly changing outside environment. A breach in the side of the mound lets turbulent wind energy penetrate deep into the mound, including as far as the normally placid nest environment. Damage to the mound thus elicits alarm in the nest due to wind-induced rapid perturbations of the nest environment—puffs of air—as well as fluctuations in the levels of CO_2, oxygen concentration and humidity. The alarm that spreads through the nest, either directly or vicariously, mobilizes termites to leave the nest and venture into the mound.

Once in the mound, the termites' repair efforts should ideally be focused on the site of the damage. The termites drawn into the mound during the recruitment phase operate in a climate of deep uncertainty, which complicates their ability to find the actual site of damage. The worker termites are blind; the main source of information for them is the intensity of turbulence-induced perturbations of the mound environment, which are chaotic and unpredictable. As a result, there is little correlation between the perturbation intensity a termite might feel locally and proximity of the actual source of the disturbance, namely the breached surface of the mound. To successfully undertake the repair of the damaged mound surface, the recruited termites must collectively make decisions on where repair work is to be done.

The typical course of this decision-making process begins with the recruited termites posing many "hypotheses" of where in the mound the damage is, followed by a winnowing of incorrect hypotheses until the correct one—building at the site of damage—wins. Practically, this involves competition between two drivers of termite building. The first is a perturbation-induced building behavior, whereby termites exposed to some critical perturbation intensity begin to lay down moist dollops of soil on a tunnel surface. We call this perturbation-induced building. The second driver follows from the first. A dollop of soil laid down by a termite contains within it an attractive pheromone—the cement pheromone—that stimulates other termites to build upon it. This process is known as stigmergy (Bonabeau et al. 1997; Grassé 1959; Werfel and Nagpal 2006), and we call the behavior stigmergic building. Although stigmergy is usually presented as the sole driver of building behavior, it is only one of several drivers of termite building.

Shortly after damage to the mound, recruited termites begin building at numerous sites throughout the mound. Perturbation-induced building is the strongest driver of building at this stage, and each site—chosen because of a gust of wind—represents an initial "hypothesis" on where the damage is. Once these hypotheses have been posed, each site competes with others to recruit termites into stigmergic building. Those sites, or hypotheses, that draw termites into stigmergic building can be said to be winning, while those that lose termites are said to be losing.

During the course of mound repair, there is a gradual shift away from perturbation-induced building, allowing stigmergic building to prevail. As the competing sites build, the tunnels within the mound become partially blocked, which eases the admission of turbulent wind, and hence diminishes the importance of perturbation-induced building throughout. Gradually, workers begin to abandon building sites where perturbation intensity is lessened, and converge upon the site where perturbation intensity remains high—near the breach. This phase of mound repair ends with a plug at the breach site, and numerous abandoned building sites scattered throughout the mound.

What's left behind by this repair crew is something akin to the scar tissue that forms over a cut in the skin. In fact, the dynamics of wound healing in the skin are very similar to the dynamics of wound healing in the termite mound. The presence of this scar tissue, if you will, is the inducement for the next, longer phase of restoring the mound to its functional integrity. Each site of mound repair, whether it be the convoluted spongy build at the repair site, or any of the numerous sites of aborted building throughout the mound, presents surfaces that are highly curved, with small curvature radii compared to the surfaces of the mound tunnels. The repair build is also much more friable than the typical smooth surface of a functional mound tunnel. Both are powerful inducers of building behavior. When a termite encounters a friable and highly curved surface, it begins to dismantle it and spread the soil around, making the interior surface of the tunnel smoother and more expansive. This process, repeated innumerable times, restores the tunnel to its original form prior to the damage.

7.5 Swarm Cognition in Mound Construction and Design

Thus, we see that the process of mound repair is not really directed by any central process or direction, but rather is an ongoing cognitive process, where cognitive agents—the termites—receive and process information about their environment. This information includes both physical perturbations and how their nest mates are responding to them, either directly, as when one termite communicates directly to another, or vicariously, as when one termite encounters a structure built by another. Vicarious encounters represent a sort of social memory, which can span generations; the extended remodeling stage can play out over multiple years, much longer than the lifespan of worker termites.

Mound repair is a microcosm of the broader phenomenon of mound construction and design. The mound normally functions as a well-designed physiological interface between the nest and atmosphere, allowing the colony to tap kinetic energy in turbulent wind and harness it to power gas exchange in the colony. The mound does not start out that way, however, and the emergence of mound design is a dynamic process similar to mound repair.

The principle motivating force behind mound construction is not gas exchange, but water balance in the colony. The translocation of soil from deep horizons up into the mound does not appear to be motivated, initially at least, by any functional demands for gas exchange. Rather, it is the need to export excess water percolating into the nest during the rainy season that provides the initial impetus for mound building. In so doing, however, the colony extends the reach of its "internal" air spaces up into the turbulent boundary layer, exposing these to the disrupting influence of turbulent wind. Termites venturing into this newly disruptive environment are exposed to the same perturbing influences that trigger termites to repair a breach in the mound. Thus, a mound starts off as a "rough draft" to fix the water problem, which is then shaped and refined into its final design by the rough draft's functional imperfections with regards to other environmental factors.

The processes of mound repair and mound design are remarkable in themselves. Even more remarkable is the complete absence of a plan for the mound or the construction process. Rather, each mound is the outcome of a multi-scale cognitive phenomenon. Individual termites act as cognitive agents, but combined with direct and vicarious interactions among all the colony's cognitive agents, some of them involving remarkable feats of memory, the entire colony—termites, their constructed environment and the physical infrastructure—acts as a cognitive entity as well.

7.6 Lessons for Urban Planning

Are there any lessons for human urban planning to be drawn from the termite "city"? I'm in no position to answer on any terms but the baldly speculative. Nevertheless, I will share two personal, idiosyncratic thoughts that may be illuminating.

Recently, I was privileged to spend some time at a prestigious research institute in Bangalore, India. The anecdote I wish to share has less to do with the wonderful time I spent there as it does with the—at first sight—less wonderful Indian traffic. My first experience of it was the late-night drive from the airport to the institute, which had assigned a driver to pick me up. The road that serves the airport is a modern dual carriageway, with all the appropriate lights, markings, road verges and medians. Within minutes of leaving the airport, we encountered a car traveling our direction on the wrong side of the dual carriageway. Both drivers responded with cool indifference.

Closer to the city of Bangalore, the dual carriageway is more used, but still equipped with all the usual accouterments of well-ordered traffic control: lane markings, traffic lights, traffic control signs, medians. As we traveled into the city, traffic became heavier and more chaotic, and obedience to the dictates of traffic control seemed ever more optional. Even physical barriers like median strips and curbs did little to dissuade drivers from finding alternative routes; all seemed determined to reach their destinations quickly, through roads jammed with busses, lorries, automobiles and swarms of motorcycles, scooters and motorized rickshaws. Added to the mix were pedestrians and the occasional garlanded cow, all enveloped in an exhilarating cacophony of tooting horns, flashing lights, hand signals and subtle glances between the innumerable drivers. At the time, I thought this chaotic traffic must be something out of the ordinary, perhaps caused by road construction or repair. My subsequent forays into the city of Bangalore quickly disabused me of any such thought. I was never more glad to have had a driver assigned to me.

My reason for relating this tale is to underscore another thing I noticed: I did not witness a single collision. I followed up on this counter-intuitive thought, and it turns out that it has some grounding in truth. World Health Organization statistics show that traffic fatalities in India overall, while they might be higher than in the United States, nevertheless rank among the lower tiers of traffic fatalities worldwide (2014). By far the most dangerous traffic in the world is generally to be found in Africa: Namibia, a country with which I have considerable personal experience, has the highest rate of traffic fatalities worldwide, despite having strict traffic laws and a superb infrastructure of roads and traffic control. Delving more deeply into the statistics for India reveals that the fatality and accident rates in the typical traffic environment of an Indian city are actually among the lowest in the country (Kumar 2012). Furthermore, the most numerous class of vehicles in this environment—motorized rickshaws and motorcycles—which Smeed's Law would lead us to predict to be the most collision-prone class of motor vehicles (Adams 1987; Smeed 1949), are actually among the safest motor vehicles of all on Indian roads. Indeed, according to the WHO, the largest downward driver of traffic fatalities has not been more stringent traffic control, but increased attention to safety equipment: better use and design of passenger restraints, such as helmets, and better engineered vehicles (World Health Organization 2014).

This little digression has a germane point. The cacophonous traffic I witnessed in India is a classic example of a self-organized system (Bonabeau et al. 2000; Camazine et al. 2001). It works better than one might expect it to because humans, it seems, do remarkably well at navigating themselves safely through chaotic and randomly changing environments, such as the wild roads of Bangalore. Key to this is the ability of the innumerable cognitive agents in this swarm to convey information to one another about individual intentions and motivations. In Bangalore traffic, this occurs through the medium of the symphony of sounds and signals the drivers convey to one another. In this environment, top-down traffic regulation verges into the realm of dangerous distraction, which is presumably why it is so widely ignored.

This brings me to the second personal anecdote, one more directly pertinent to the topic of this conference. I made my home in South Africa for several years, around the time of its transition to full democratic governance. During that time, I witnessed the easing of many of apartheid's onerous provisions, including the relaxation and eventual repeal, in 1991, of the Group Areas Act. The Act was one of apartheid's mainstays, and, a masterpiece—both wondrous and chilling to behold—of top-down urban planning. Its abolition could not have been more welcome: Many of the horrific incidents that played out again and again during my time there involved the bulldozing and burning of the numerous informal settlements—shantytowns—that were springing up around South Africa's urban centers. These informal settlements, driven by the increasing urbanization of South Africa's population, were stark evidence of the failure of the Group Areas Act pipedream to control how and where people lived. The bulldozers were driven not so much by racist animosity as they were by an attempt to re-impose zoning control.

Since that time, the development of the South African urban landscape has been mixed. A common trope one hears in South Africa is that South Africa's major urban centers—Cape Town, Johannesburg, Durban—are now becoming "African cities." This is usually code for the emergence of an exhilarating, if somewhat disorderly, dynamism: downtowns filled with people, informal markets, stalls and entrepreneurs—an irrepressible breakout of life that is difficult to view in anything but a positive light. For all this, the shantytowns of the apartheid era have not disappeared. Indeed, they are expanding, their growth driven by the same inexorable urban migration that drove their growth during the apartheid era. Sadly, the razing of informal shantytowns has also not stopped: the actors and justification may differ but the forces driving the bulldozers and demolition crews remain.

This mixed legacy is explored in Murray's (2008) illuminating study of the developing urban landscape in post-apartheid Johannesburg, *Taming the Disorderly City* (2008). According to Murray, the impulse to control urban development from the top-down, so to speak, remains strong, but is being ever more strongly challenged by the insistent bottom-up desires that were liberated in the aftermath of apartheid.

Both my Indian and South African anecdotes underscore a fundamental dilemma: How do well-functioning complex systems and structures emerge from the behavior of many agents working in a cooperative assemblage? It is a question that is animating all students of complex systems, from biology to robotics, traffic control or the planning of our own environments; the question is driving a fascinating paradigm shift in all these fields.

In biology, the emergent complexity of living systems has long been thought to be specified, with genes being the ultimate specifiers (Turner 2013a). Good function, let us rather call it apt function, is specified by “apt function genes.” These are the product of past natural selection: genes that specify apt function are selected against genes that specify “inapt”, or less apt function. Over many generations, there emerges a prevalence of apt function genes that specify the remarkable complexity and adaptation we see in the living world today. These genes, then, are the repository of past accumulated wisdom of how to build an orderly and well-functioning organism. But this scenario is missing living systems themselves, and the wants and desires that exist independently of what genes specify for living systems.

It’s my understanding (perhaps erroneous) that a similar mindset has sometimes prevailed in urban planning and architecture. Architects, engineers and planners, like genes, act as repositories of the accumulated knowledge of past good, bad and indifferent design. Just as with genes, architects and planners act as design specifiers, with their designs representing the accumulated wisdom of their art. There is a danger that wisdom can become license, as in the designs of Le Corbusier or the Bauhaus, where the end users of the designs almost became an afterthought: When users are simply expected to accommodate themselves to whatever designs are specified for them—regardless of individual wants and desires—license has gone too far.

In biology, the gene-as-specifier mindset is looking ever more impoverished and —there is no other way to put it—wrong, as we are coming to appreciate what Cannon (1932) called the wisdom of the body concerning the self-emergent stability of organisms (1932), and what Tom Seeley has termed the wisdom of the hive,concerning similar levels of bottom-up stability of the social insect colony (Seeley 2009). In both conceptions, we see genes in their proper perspective—not as top-down specifiers of complex systems, but facilitators of the infinitude of cognitive conversations among the “many little lives” that compose the complex organism or superorganism (Turner 2013b). This seems to me, a mere biologist, to describe what should be a best practice for urban planning: not specification, or the ill-advised attempt to impose order, but facilitating the ability of the many cognitive agents that make up our cities to judge their environments for themselves. The individual judgments of citizens can combine into a collective best practice for how to best construct the city.

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Chapter 8
Physical, Behavioral and Spatiotemporal Perspectives of Home in Humans and Other Animals

Efrat Blumenfeld-Lieberthal and David Eilam

Abstract Home is usually considered as a physical construct of residence. In both humans and non-humans it has a functional partitioning into room for living, storage, toilets and other defined activities or services. Home is first and foremost where a set of behaviors are performed at rates higher than anywhere else; in rats, home is defined by sleeping, long stays, food hoarding and parental behavior. Another conspicuous feature of home is identity, which is constituted by the collection of inanimate objects, furnishings and gadgets that personalize each individual's home. Security is another aspect: home is where you feel safe, and your privacy is protected. Moreover, home behavior is a strong trait that it is manifested even when a physical home is lacking, such as in the case of homeless humans and other animals. Finally, spatiotemporal behavior in the living environment is organized in relation to the home. Indeed, home is a hub for activity, with both humans and non-humans taking trips out from and back to their home, traveling regularly along the same paths and usually stopping at the same locations along them. While there are obvious differences between humans and animals, there are many similarities, and by focusing on the latter, it is suggested that similar biobehavioral systems in humans and non-humans account for the convergence of home behavior to these similar traits.

8.1 Prolog: Home, Home Behavior and Home as an Anchor for Spatial Behavior

On the morning of September 17, 1832, while visiting the Galapagos archipelago, Charles Darwin watched the local giant tortoises (*Testudo nigra*) in fascination, and wrote: "When I landed at Chatham Island, I could not imagine what animal traveled

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so methodically along well-chosen tracks. Near the springs it was a curious spectacle to behold many of these huge creatures, one set eagerly travelling onwards with outstretched necks, and another set returning, after having drunk their fill" (Chatfield 1987). Darwin also described the regular trips taken by these turtles, which could extend over several miles and last several days, evidence of their large familiar living environment. The turtles also displayed a coupling between specific behaviors and locations, as, for example, they did upon reaching the target of their journey: "When the tortoise arrives at the spring, quite regardless of any spectator, he buries his head in the water above his eyes, and greedily swallows great mouthfuls, at the rate of about ten in a minute" (Chatfield 1987). A century later, Konrad Lorenz, pioneer of the study of animal behavior and Nobel Prize laureate, described an analogous tendency of animals to travel along fixed routes and display regular behaviors in specific locations. Lorenz described the water shrew as a creature of habits: "Once the shrew is well settled in its path-habits, it is strictly bound to them as a railway engine to its tracks… Alteration in the habitual path threw the shrews into complete confusion." He observed that a shrew used to jumping above a stone on its familiar path continued to jump in that location after the stone had been removed, time and again, as if disbelieving its senses' report of a change in its habitual environment, and necessitating a consequent alteration of the habitual behavior (Lorenz 1952, pp. 127–8). Lorenz, with a touch of anthropomorphism, described the same tendency of habitual spatiotemporal traveling in his own behavior: "When driving a car in Vienna I regularly used two different routes when approaching and when leaving a certain place in the city… rebelling against the creature of habit in myself, I tried using my customary return route for the outward journey and vice versa… the astonishing result was an undeniable feeling of anxiety, so unpleasant that when I came to return I reverted to the habitual route" (Lorenz 1974). Indeed, traveling methodically along specific routes in a specific territory and regularly displaying specific behavior in specific locations reflects spatial behavior in humans and other animals. Inspired by Darwin's observations, Hediger (1964) described habitual spatiotemporal behavior in the framework of animal territory (Fig. 8.1). The diagram shows that territory is perceived as a set of locations, in each of which the animal demonstrates a specific behavior. These locations are interconnected by a set of regular paths, which together form a map-like layout of the living range. The hub for the activity in this territory is the 'home'—defined here as the location with the highest connectivity to other locations. Home (or the home base) is also a hub of spatiotemporal behavior in humans, with over 50 percent of their daily trips being home-base generated (Golledge 1999b, p. 26). Indeed, for both humans and non-human species home is the dominant anchor point for spatial behavior in the territories over which they range. Accordingly, both humans and non-humans need to determine a home location, memorize its position and locate landmarks or other spatial information in relation to it in order to be able to end a journey away from it and return directly to the home (Golledge 1999a). While it is possible to define home as a place featuring exclusive

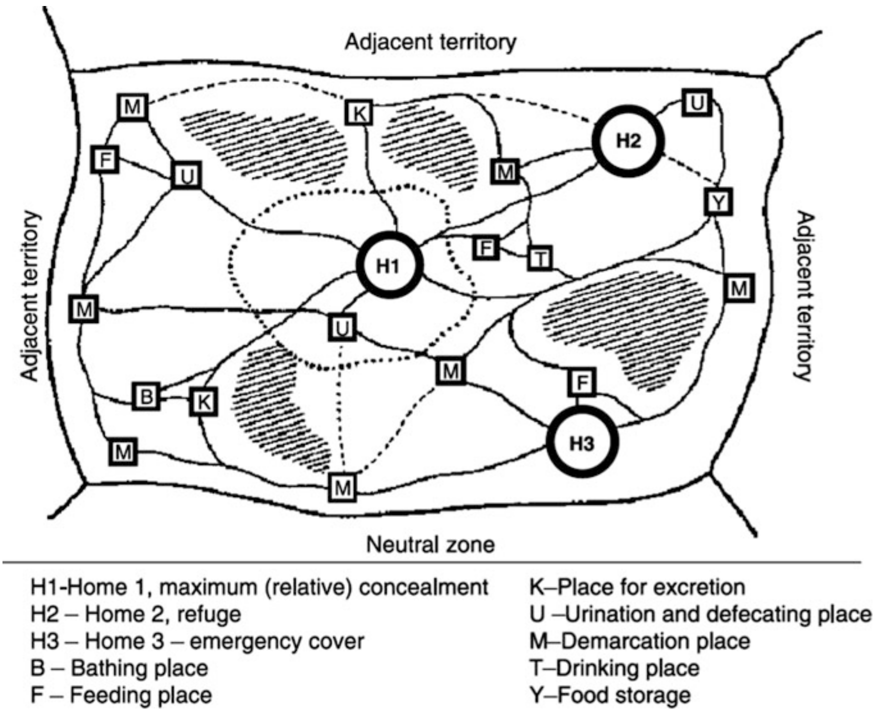

Fig. 8.1 The structure of territory, (after Hediger 1964; with permission of Dover Publications). The territory comprises main, secondary, and emergency home locations (*H1*, *H2*, and *H3*). These homes and another set of locations, each with a typical behavior (marked by *squares* and explained in the legend), are connected by a network of routes (marked by *lines*)

behaviors that are rarely performed elsewhere, the impact of home on spatial behavior extends beyond its physical limits; home impacts the organization of spatial behavior throughout the living range.

The scope of the present survey relates to home and home-related behavior in humans and other animals. Specifically, we first explore home as an abstract term, then as a physical construct. We next discuss home-related behaviors, suggesting that home is predominantly a behavior and state of mind. We also describe how spatial behavior throughout the living range is organized in relation to home, thereby extending the impact of home beyond its physical limits. Finally, we discuss how home behavior is manifested even when a physical construct of home is lacking, as in the case of homeless humans and other animals.

8.2 "There Is No Place Like Home"—Home as a Physical Construct on Different Perception Scales

For humans, the word *home* can relate to different terms on different scales. On the individual scale, a home may refer to one's residential arrangement: a house, a housing project, even an outdoor location in the case of a homeless person. On a larger scale, home can be a town, hometown, a country or a homeland. On a universal scale, Earth is home for astronauts—and for us all. Indeed, when in space, astronauts spend much of their time earth-gazing: "We have this connection with Earth, I mean it's our home," mused Nicole Stott, Shuttle ISS astronaut. She also described a great sense of responsibility and a need to take care of Earth, our home, after contemplating a cosmic view of it from space. This astronaut's reaction seems similar to the sense of ownership, responsibility, identity and security that one can feel for one's home, hometown and homeland, but astronauts project this sense upon Earth.

From a very narrow perspective, 'home' is a spatial construct for both humans and other animals, and as such it is usually described only according to its physical properties, such as structure, location and size. In humans, home spatial partitioning is basically functional: living room, parents' room, kids' rooms, kitchen, bathroom, storage, etc.; whereas for many animal species, 'home' is usually regarded simply as a den, nest, burrow, or other type of sheltered location. A more detailed examination, however, reveals similarities between the functional partitioning in humans and non-humans. For example, rats introduced into live in a large room gradually organized the space into nesting sites, food stores, runways, and latrines (Leonard and McNaughton 1990). Similarly, rodents kept in small standard rodent cages ($40 \times 25 \times 20$ cm) nest in one corner, store food in another corner, and use another corner as latrine. The functional partitioning of home has been noted also in the wild, as illustrated in den structure in various species. For many species, the den is a simple straight burrow cambered at the end. For example, a female polar bear (*Ursus maritimus*) in winter time digs in the snow a 600 cm-long den comprising a single entrance/egress tunnel ending in a $148 \times 127 \times 79$ cm oval chamber ("living room") and a few ventilation holes. The chamber usually includes a nest-like depression, where the mother and cubs spend most of their time. This basic structure, however, greatly varies among individuals, with some dens having two chambers, others having two openings, and yet others possessing multiple chambers and additional tunnels (Durner et al. 2003; Fig. 8.2).

The long-eared hedgehog (*Hemiechinus auritus*) also dwells in a simple burrow which becomes larger at the end. In the breeding season the mother adds another chamber for her newborn pups while she inhabits the other chamber (Mendelssohn and Yom-Tov 1999). A similar simple burrow can also be found in invertebrates (Christy 1982). The blind mole rat (*Spalax ehrenbergi*), a solitary rodent, lives in a subterranian burrow system (Fig. 8.3). Above ground, this burrow system can be recognized through the series of *equispaced* soil mounds that the mole rat excavates to the surface while digging. The mole rat lives its entire life inside the burrow

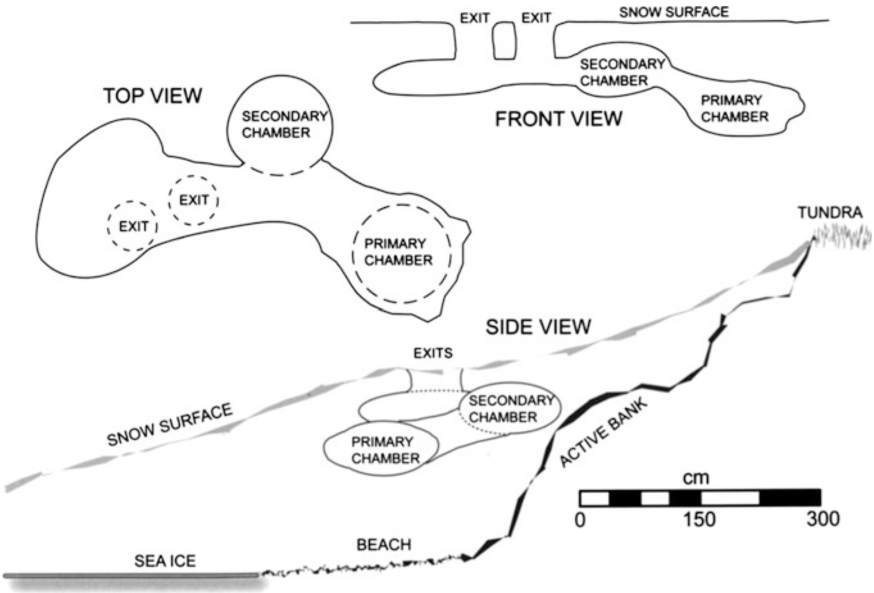

Fig. 8.2 Diagrams of a polar bear maternal den near Prudhoe Bay, Alaska, 10 April 2000. After Durner et al. (2003) (with permission of the authors and the Arctic Institute of North America)

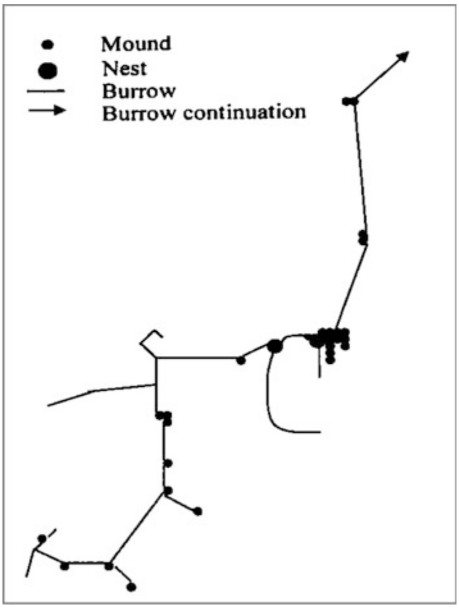

Fig. 8.3 The burrow system of a mole rat. The location of above-ground mounds is depicted by *small circles*, and the two nest locations by *large circles* (based on Erez 2005)

without ever emerging above ground, and accordingly, the burrow system incorporates nest, several storage chambers, and latrines. During the breeding season the female expands the nest, which can be recognized through the nearby larger excavated soil mound (Erez 2005; Zuri and Terkel 1996). Finally, social animals may construct a structured communal home with apparent functional partitions and labor division (Turner, this volume). Fat sand rats (*Psammomys obesus*) construct a multi-level burrow system with numerous compartments for harvesting food, latrines, nesting chambers, etc. (Mendelssohn and Yom-Tov 1999). Social voles (*Microtus socialis*) live in extended families of parents and several successive generations of offspring. Several families inhabit together a large complex network of burrows with several openings to the outside, and numerous chambers into which they hoard grains and vegetation (Cohen-Shlagman 1981). Rabbits (*Oryctolagus cuniculus*) too dwell in burrow systems, which despite their complex appearance, always follow three rules: (i) size; (ii) negative correlation between the number of holes and depth; and (iii) negative correlation between the number of junctions and length of burrow sections (Kolb 1985). Thus, despite the variation found among species and among individuals of the same species, there is a basic general plan of a 'den' and it is always used as a place for rest, shelter from predation and/or weather, and in which to rear offspring. Rather than a den, some animals establish their home inside a bush, under a rock, in a crack or cave, in a hollow or cavern, etc. Likewise, a variety of dwelling constructs can be found in humans too: house, apartment, building, mobile home, houseboat, yurt, communal town, village, suburb, city, county, etc. The resemblance of 'home' as a physical construct between humans and other animals becomes more apparent when a 'home' is considered as a state of mind and as the organizer of behavior in time and space.

8.3 "Home Is Where the Heart Is"—Meaning, Emotion and Behavioral Perspectives of Home

Home has been described above as a physical construct for dwelling. In addition, and perhaps foremost, it also involves 'home behavior'—a set of typical activities and emotional states that are firmly coupled with the physical location, expanding the meaning of home to the behavioral-emotional domain. Home behaviors are usually derivate of its role as a hideout, and a place for both resting and nursing. Indeed, behaviors such as sleeping and crouching, long stays, food hoarding and parenting are performed at home at rates higher than anywhere else. Home is a place of comfort. We say that someone feels at home when an individual is relaxed, free and confident. We encourage someone to make themselves at home, or declare that "our home is your home"—phrases that explicitly attest that home is not just a physical place but also a state of mind, with characteristic home behavior. Certainly, home is the place where one can be more oneself than anywhere else (Burnard 1999).

Generally speaking it can be argued that, for humans, home has social and physical characteristics that influence the behavior within it and in relation to it (Lang 2007). The rituals involved in entering the home of another (knocking or ringing the bell) have been compared with the recognition ceremonies of nesting birds (Guhl 1965). Porteous posited three essential territorial perspectives of home (1976): identity, security and stimulation. Identity is reflected in the personalization of the home: the collection of inanimate objects, furniture and gadgets that one transfers when changing home. Upon moving to a new home, it is the unpacking and arranging of the objects that renders the feeling of home. Sometimes it is even enough to look at the boxes and imagine where the objects within will be placed in order to confer the feeling of a new home (Wise 2000). From this perspective, home is composed mainly of location-specific behavior and individual identity, and not merely of physical properties: “It was not the space itself, not the house, but the way of inhabiting it that made it a home” (Boym 1994). This statement connects to Jung’s physiological perception that home is a symbol of the self: by designing one’s dwelling, one in fact tries to express the way one would like to be perceived, one projects an identity. The way one arranges the home can be related not only to one’s persona, but also to one’s culture. This has been illustrated in a comparison between the traditional Muslim dwelling, in which the public and private areas are rigidly separated, and the contemporary Western dwelling, in which open spaces reflect a more equal relationship between the family members as well as a higher level of similarity between their private and public lives Sebba (1996). Personalization of the home reflects both identity and security needs, which are achieved respectively by the constant modifications and defense of the home. This constant change and maintenance of the home provides stimulation—the third essential territorial perspective of home (Porteous 1976). Indeed, home revolves around a sense of ownership and safety. It provides privacy and a refuge from voyeurism (Douglas 1991), prompting a strong urge to protect the home in turn. In this context, it is clear why homeowners are swamped with feelings of insult and anger if their home suffers a break-in or burglary, as well as an accompanying fear that comes from having their privacy and safety undermined.

Returning to the multi-scale meaning of home, we can contend that similar processes affect the way that one perceives home on higher scales: many cities or towns possess a specific identity. Examples of this can be found in the nicknames of cities, such as Nashville “music city” or Reno, in Nevada, whose nickname “The Biggest Little City in the World” is proudly proclaimed by a sign on a Downtown street. An example of a modification in a city’s identity is that of Tel-Aviv, which re-invented itself in the 1980s with a new urban plan and a new urban slogan: “Tel-Aviv—the city that never stops.” This, together with other activities, transformed Tel-Aviv from a city that was growing older in terms of its population into a center of attraction for young people Blumenfeld-Lieberthal et al. (2009). In the same vein, with the expansion of home identity to one’s home town, a sense of security is also applicable on a larger scale, with cities providing municipal services such as a police force or social security services on both the national and municipal scales. The sense of security can also be expanded to include economic security.

At the national scale we find all of Porteous' three essential territorial properties: identity, security and stimulation. In terms of identity, nationality has always been related to both a set territory and the identity of its inhabitants Knight (1982), Hooson (1994), He and Guo (2000), Blank and Schmidt (2003). Personal identities are always defined in part by nationality, as people are classified by their passports or other official identity cards. Nationality is usually based on the place of birth and where one is raised (i.e. one's homeland) and not necessarily according to the current place of residence. The expression of a national identity different to the place of residence can be seen in immigrants who maintain a relationship with other immigrants from their place of birth, and even form new communities based on their country of origin in their new places of residence, such as the Chinatown found in major American cities. Zali Gurevitch tells an anecdote relating to this behavior, based on Daniel Defoe's *Robinson Crusoe.* Crusoe's action of building a home on the island began by saving whatever he could from his sinking ship. He used these possessions as the foundations for his new home, which was based on the culture of his homeland. In fact, Crusoe did exactly what immigrants do; he established a cultural bubble that reconstructed his origins. For ten months he worked on building his new home without exploring what the new location might have to offer even once.

Security is one of the basic demands one makes on one's country. In contrast, the term "refugee" refers to those who do not have a sense of security in their homeland and thus must flee in order to find refuge elsewhere. To ensure the security of their inhabitants, most countries strive to develop the best possible army, and maintain it even in times of peace. On the national scale, identity and security are intertwined; many wars began or evolved based on identity differences between the combatants, whether in terms of religion (the Crusades), race (the Holocaust), or other national identity markers—with nations seeking to defend or expand their identity and territory. Additionally, in-house debates and even civil wars that affect security have often been related to the identity that the citizens want to embrace (the American Civil War in the nineteenth century and the French Wars of Religion in the sixteenth are both good examples). And, similarly to stimulation on an individual scale, maintaining (or developing) a country's identity and security provides constant stimulation.

Animals are not unlike humans in their sense of home. The following anecdote about animals moving objects to a new home comes from one of my early studies with tamed wild rats. One female rat that had become my pet used a piece of bubble-wrap as a blanket. The rat would pool the cage bedding (wood shavings) to make a crater-shaped nest and, upon entering the nest, would pull up the bubble wrap to cover the nest from the top. After some time, I introduced a smaller cage with a male rat in it into her cage, enabling them to sense and sniff each other through a wire mesh without physical contact. A few days later, I opened the door of the male rat's cage, allowing the rats to meet with no barriers. The female, more confident by virtue of extensive taming, immediately entered the male's nest box and, after a few minutes of extensive sniffing and interacting, ran back to its own nest to take the sheet of bubble-wrap to the male's nest, where they then nested together. The scenario reminded me of my daughter moving in with her boyfriend.

Home behavior is characteristic of rats. It is such a strong trait that it is manifested even when a physical home is lacking. When a rat (or another rodent) is placed in an unfamiliar environment, it soon establishes a home base (Eilam and Golani 1989). If a salient landmark or a shelter is accessible, then the home-base location will be near or inside this landmark. However, in an homogenous environment with a minimum of spatial cues, the rat will usually establish a home base at the point at which it was introduced into the environment (Nemati and Whishaw 2007; Yaski and Eilam 2008). Even when there are no unique physical markers for a home base, its location is clearly distinguished from other locations by virtue of the typical behaviors displayed there: the rat stays at the home base for a much longer duration than any other place, it crouches there, returns to it frequently after exploring the environment and regularly grooms its fur and rears up on its hindquarters there (Eilam and Golani 1989). In sandy environments, the rodent will also start digging a burrow in the home-base location; paradoxically, gerbils display extensive digging behavior at the home base even on tiled floors. Home behavior is thus an inherent property of the animal and, accordingly, is displayed even in the absence of the desired physical construct of home. The comforting effect of home behavior is conspicuous in both humans and non-humans, and it is this behavior that individually marks and territorializes similar spatial physical constructs (such as similar apartments in the same building) into one's specific home.

8.4 "Time to Go Home"—The Spatiotemporal Perspective

As described above, the home base in rats serves as a terminal for round trips in the environment. These round trips have a characteristic structure: their outbound segment is slow and interrupted with stops, whereas the inbound segment is fast with fewer, if any, stops (Eilam and Golani 1989). Regardless of round-trip length, there is an upper limit of 8–10 stops per trip, and once this limit is reached, the rat usually dashes back to the home base (Golani et al. 1993). Accordingly, exploration in home-base behavior is conceived of as a set of round trips that are anchored to one specific location—the home base (Fig. 8.4). In restricted laboratory settings, behavior in time and space is thus organized in relation to the home base (Eilam 2010; Eilam and Golani 1989; Hines and Whishaw 2005; Nemati and Whishaw 2007; Yaski and Eilam 2007; Zadicario et al. 2007).

The role of home as a terminal, or a hub, for traveling in the environment is illustrated in Fig. 8.1, a diagram of the structure of a typical territory or living range. In nature, many animal species live within a confined and limited range, which is dictated by various factors such as other individuals of their species, other species, food resources, topography, available shelters, physiology, and social rank. Within the living range, animals may define and protect a limited area, preventing others from using it—this is a territory (Immelmann and Beer 1989). In other words, when animals repeatedly use the same specific area in the course of their activity, they can be said to possess a home range (Barrows 1996). The home range

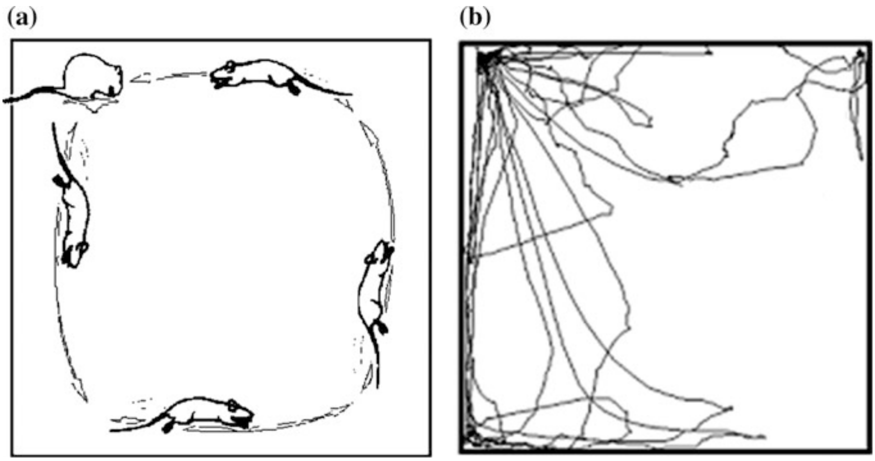

Fig. 8.4 A diagram of round trips to the home (**a**) and the actual trajectories of periodic returns to the home base in a gerbil-like rodent (**b**)

is usually defined as the area within which a high percentage of activity (95–99 %) takes place (Anderson 1982; Don and Rennolls 1983; Matthews 1996). Accordingly, it is assumed that by having a home range, animals increase the efficient use of resources (such as food sources and refuge sites). The shape and size of a home range is highly variable, as is illustrated by fish (Kramer and Chapman 1999). In coral reef fishes, for example, there is a direct correlation between body size and home range. While some coral reef fishes move on a daily basis between sites used for feeding and those used for reproduction or resting, other species are relatively stationary (Kramer and Chapman 1999). Three broad daily movement patterns were observed in fish: (i) commuting, with crepuscular shifts in habitat or location; (ii) foraying, occupying the same refuge holes between day and night; and (iii) mixed, which is a mixture of commuter and forayer movement patterns (Marshell et al. 2011; Meyer and Holland 2005). In a home range or territory there are three prominent behavioral characteristics, two of which are shown in Fig. 8.1: (a) traveling regularly along the same paths, (b) periodic returns to the home.

8.4.1 Regular Traveling Along the Same Paths

At the beginning of this article we described how Darwin was fascinated by the vision of turtles traveling methodically to the springs. Routes leading to scarce vital resources, such as water holes, are the most recognizable of animal tracks as the intensive use of these routes clears them from vegetation. A study of the behavior of black rhinos (*Diceros bicornis*) offers a good example (Schenkel and Schenkel-Hulliger 1969). Traveling repeatedly along the same route is made possible by both internal cues (such as vestibular information on turns or odometry) and external cues. The latter can be directional cues that polarize the environment; for example, chemical, magnetic or light gradients. These cues enable navigation through an unknown environment by means of forming a one-dimensional map. Directional cues are prevalent in aquatic environments and when visibility is poor. Other environmental cues are positional, comprising landmarks that are used to deduce distances and directions of a specific location in the environment (Jacobs and Schenk 2003). Both directional and positional cues enable repeated traveling along the same path. For example, when salmon return to their *home* to spawn (where home is understood as a place of origin) they are guided through the visually homogeneous ocean, at least partially, by chemical and magnetic cues. In contrast, fish species belonging to the coral feeding guild rely on landmarks afforded by the structured coral reefs (Reese 1989). An example is the foraging butterfly fish. These coral-dependent fish swim within their territories and home ranges along a predictable pattern from one food patch to another. The pattern is based on learned coral head shapes; when these are removed the fish look for them in their former location. Moreover, when these fish are deflected from the path, they resume their regular pattern upon encountering the first familiar landmark (Reese 1989). The ubiquity of regular traveling along the same routes in vertebrates, as illustrated by fish, has also been demonstrated in primates. In a study, baboons (*Papio hamadryas*) were found to sleep on two cliffs and to travel daily along four routes between these cliffs (Schreier and Grove 2014). Another study revealed that baboons change their direction of travel at fixed locations where they turn back to their sleeping site or head towards locations next to important landmarks (Noser and Byrne 2014). Similarly, tamarin monkeys (*Saguinus fuscicollis*) travel along regular paths while attending to near-to-goal landmarks (Garber and Porter 2014); bearded sakis (*Chiropotes sagulatus*) appear to encode the locations of high-quality food patches and minimize travel routes between them (Shaffer 2014). Finally, spider monkeys (*Ateles belzebuth*) and woolly monkeys (*Lagothrix poeppigii*) typically travel through their home ranges by repeatedly following the same routes. Their routes remained stable over eight years of observation, and appeared to be associated with easily recognized landmarks (Di Fiore and Suarez 2007).

Classic models that sought to describe human spatial behavior, also known as human mobility patterns (HMP), used Brownian motion or random walk to describe it (Camp et al. 2002; Groenevelt et al. 2006; Loannidis and Marbach 2006). These models assumed that human movements present a pattern of a successive number of random steps, in terms of distance and direction. In the last decade or so this perception has changed due to the greater availability of empirical data provided by the Internet and mobile phone usage. For example, based on data from the website www.wheresgeorge.com, which tracks the location of numerous banknotes over time, it has been suggested that HMP follow a Levy-flight distribution (Brockmann et al. 2006). Implicit in this observation is that, while the direction of the movement was considered as random, the distances followed a power law distribution—there were many short trajectories and very few considerably long ones. A study of the trajectories of 100,000 mobile-phone users over a period of six months revealed that HMP not only follow a Levy-flight distribution, but also present a high degree of regularity in time and space (Gonzalez et al. 2008). These findings were supported by GPS data (Zhao et al. 2008) and data from another 50,000 mobile-phone users over a three-month period, concluding that "despite our deep-rooted desire for change and spontaneity, our daily mobility is, in fact, characterized by a deep-rooted regularity" (Song et al. 2010). These empirical findings suggest that people have a routine of returning to several specific places, of which the most common are one's home and work or school. Strikingly, while social relationships can explain about 10–30 % of all human movement, periodic behavior explains 50–70 % of it (Cho et al. 2011). These findings were strengthened by a study of the behavior of carpool users and route characteristics in Taiwan, which revealed that 73.9 % of carpools consist of regular routes (Chung et al. 2012).

The notion that people travel along temporal and spatial routines has been called "time geography" (Hägerstrand 1970). Later studies sought explanations for these behaviors by relating HMPs to the underlying topology of street networks (Jiang et al. 2009), as well as to the scaling and hierarchical properties of the destination clusters and people's individual preferences (Jia et al. 2012). In contrast, Noulas et al. suggested that HMP results from the various and different objectives that drive a person's decision to move (2012). Specifically, this study found that the probability of moving from one place to another is dependent on the number of intervening opportunities between the origin and its destination, and not on the physical distance between them.

8.4.2 Permanent Places with Regular Behavior

Animals tend to regularly perform the same behavior in the same locations, as demonstrated above for home locations. Some of these behavioral regularities are enforce by topography, such as drinking at the river, feeding on particular fruit trees and sleeping on a specific steep cliff. Accordingly, regular travel along the same routes could simply be a product of a topographical bias towards desirable sites. For example, a tendency to forage in one area and rest in another has been documented in hyraxes (*Procavia capensis;* Serruya and Eilam 1996), and in vicuna (*Vicugna vicugna*; Franklin 1983). In the black rhino, regular trails connect pasture, sleeping, and drinking sites (Schenkel and Schenkel-Hulliger 1969). Pronghorns (*Antilocapra americana*) in southern New Mexico establish their home range relative to permanent water sources (Clemente et al. 1995). The traveling paths of Gibbons (*Hylobates lar*) are goal-directed: focused on their preferred food sources (Asensio et al. 2011), and a long-term retention of the location of food sites was found in chimpanzees (Mendes and Call 2014). Similarly, spiny mice (*Acomys cahirinus*) and dormice (*Elyomis melanurus*) carry snails, on which they feed, to a sheltered crevice where they crush the shell to eat its contents—resulting in piles of shells near the crevice (Mendelssohn and Yom-Tov 1999). Another form of permanent location with which regular behavior is associated is a demarcation site.

These sites are scattered across the living range to advertise either territorial ownership or reproductive state (Freeman et al. 2014). Behavior at demarcation sites is usually performed as a strict set of acts. For example, upon arriving at a demarcation site, individuals of many species of antelope first lower their head to sniff the ground and rub it with one of their forelegs. They then keep their hind legs rooted in place while stepping forward with only their forelegs, thus stretching their trunk to urinate on the sniffed site. Keeping their forelegs rooted, they then step forward with only their hind legs, thus arching their trunk to defecate on the sniffed and urinated site (Walther 1977). Similarly, black rhinos (*Diceros bicornis*) perform a fecal marking scraping ritual aimed at advertising the territories of adult males and communicating the sexual status of the females (Freeman et al. 2014). Owners of domestic animals will be familiar with their pet's preference for specific behaviors in specific locations; cats have "favored spots" within home ranges where they are likely to be found at particular times, and which they use repeatedly for sleeping, resting and grooming (Bernstein and Strack 1996). In social animals, particular locations may be shared or divided for specific activities. For example, in the hyrax's living range there is spatial separation of females and young on one side and sub-adult males on the other (Serruya and Eilam 1996). In South Africa, hyraxes diverge to occupy three areas of the living range, each of different age and gender (Fourie and Perrin 1987): sub-adult males and females, lead male and harem, and males outside the other two groups. Hyraxes in the Israeli Negev region spend about 95 % of their time crouching or traveling at a distance of a few meters from their shelter; a year-long observation on these hyraxes revealed that half of all crouches were performed on the same eight rocks or stones out of the thousands of available stones in the vicinity of the shelter (Serruya and Eilam 1996). As shown in Fig. 8.1, the living range (or territory) of animals can thus be regarded as a set of permanent locations, with a typical behavior regularly displayed at each location, and a network of regular routes connecting these locations and converging at the home, which is the core for activity within the living range. Similarly, humans tend to return to specific locations: HMP follow heavy-tailed distributions (i.e. they make many short trajectories and very few considerably long ones) with a high degree of regularity, a trait reflected in our preferences for specific locations over others. In other words, there are a few locations to which we return frequently (such as our favorite restaurant) and many other places that we visit rarely (like the unfamiliar restaurant we eat at during a conference).

8.4.3 Periodic Returns to the Home

The physical, behavioral and spatial aspects of home described above involve an additional aspect: temporal returns to the home site. Return could occur as infrequently as once in a lifetime, as in the case of salmon, eel and lamprey fishes. These fishes hatch in the beds of freshwater streams and then migrate downstream to the ocean, where they spend their life until homing back to their birthplace, to spawn and die. In other animals there is an annual periodic return to a specific breeding location. Sea turtles, for example, lay their eggs on the same beach on which they hatched. Storks spend the cold European winter season in warm Africa, then return each spring to exactly the same European location to build a nest and breed, usually after a reunion with a mate from the previous year. Storks avoid long flights over water by migrating to Africa and back either by crossing Gibraltar or crossing Israel along the Jordan Valley. The choice of crossing is not arbitrary: all storks west of a demarcation zone in Europe migrate through Gibraltar while all those east of that zone migrate through Israel. Radio-tracking of pairs in the divide zone revealed that one individual of the pair may migrate eastward and the other individual westward; they spend the winter separately in Africa before traveling back to breed together at exactly the same site (Diehn 2014). Periodic returns to the home site are more frequent in animals that do not migrate and inhabit a confined living range. Of these species, most are active at specific times, defining them as diurnal, nocturnal, crepuscular, and so on. Accordingly, they rest in a specific location—den, nest, cliff, crevice, crack, cave, hollow tree or cavern—and leave the home upon commencing their activity period, after which they return to it. In some species, activity is intermittent and constitutes several bouts that start and end at a specific site, which may be the home site. For example, social voles (*Microtus Guentheri*) forage outside for grains and vegetation which they carry back to their burrow system, where they store and harvest them in food chambers. Similarly, barn owls (*Tyto alba*) perch in specific locations from which they swoop down onto their prey. A successful hunt usually involves a return to the perch or nest site with the catch and eating it there or feeding the young, before embarking on another ambush (Shifferman and Eilam 2004). Barn owl activity may be regarded as a set of nocturnal or crepuscular hunting sessions, each starting and ending at the same perch. A similar pattern of cycles of activity and rest is apparent in the behavior of rats in an "open-field" testing arena. As described above, these rats establish a home base from which they set out on round trips in their environment. After a few round trips, the rat settles at the home base, displays extensive grooming of its fur, then crouches for a while. Later, usually after another intensive grooming session, it sets out on another round trip. As a result of this typical spatiotemporal structure of behavior, the rat displays periodic returns to the home base, which is consequently the most visited locale in the testing environment (Eilam and Golani 1989). Home is thus the major anchor point for spatial behavior, a focal convergence site for routes that typify foraging or and other activities in the living range (Golledge 1999b). To manage this effectively, humans and other animals must keep track of the home location in order to know where they are, and to locate landmarks in reference to home. Round trips or home-base generated trips dominate the activity schedules of most individuals, who upon returning to the home site display typical home behavior.

8.5 "Wherever I Lay My Hat, That's My Home": Homeless Animals and Humans

While many animals have specific home sites, other animals do not have a permanent one. These are not necessarily nomadic species, since they usually have a well-defined living range within which they display a regular spatial behavior. Darwin's tortoises, introduced at the start of this paper, are an example. Despite being encased in their shell—a self-contained home shelter, but not a fixed site—they travel methodically along fixed routes. Another example is the limpet (*Siphonaria alternate*), a sea mollusk that lives in tidal sea zones, where it shelters under its conical shell. At low tide, when exposed to the air, the limpet firmly clamps its shell to the rock, sealing in the water inside to protect it from dehydration. This firm attachment results in a circular scar on the rock surface, reflecting the boundary of the limpet shell. When covered with water during high tide, the limpet goes on a foraging journey, crawling over the rock and grinding organisms from it surface, before retracing its way back to the home scar by following the salivary trail of the outbound journey (Cook 1971). Although limpets could stop and remain sheltered at any point of their trip, they display regular spatial behavior that is anchored in a fixed location—the home scar.

Like tortoises, limpets or crabs that carry their home with them, people who do not have a house are forced to find alternative solutions for storing and transporting their possessions. A common solution is to use a shopping trolley to hold their belongings as well as foraged materials that they collect and carry to recycling centers. Homeless people often travel with the trolley at all times to avoid its theft. The trolley thus provides storage, transportation and security for their possessions (Hill and Stamey 1990). Based on homeless people's need for somewhere to keep their belongings, along with their need for a sheltered sleeping place for themselves, the designers Barry Sheehan and Gregor Timlin designed a mobile living unit for homeless people called the 'shelter cart.'[1] This unit acts as a cart during daytime and tips over to provide a covered sleeping area at night (see prototype in the provided hyperlink). Indeed, a common behavior for creating a sense of identity and self-esteem in many homeless communities (both street-dwellers and shelter-dwellers) is the accumulation of possessions that symbolize a better past or future, and thus help construct or maintain an identity (Belk 1985). Being sensitive to this psychological aspect, a US federal court decision (Lavan et al. 2012) ruled against the confiscation of homeless persons' belongings by municipalities, enshrining the rights of homeless people to keep their possessions. The nature of the importance of belongings to homeless people is comparable with the aforementioned formation of identity through home decoration and arranging ornaments in home dwellers. Implicit in this parallel is the fact that in humans, like in some

[1]The shelter cart was an entry for designboom's 'Shelter in a cart' design competition (http://www.designboom.com/design/shelter-cart-for-junk-collectors/).

animals, home-related behavior is manifested despite the lack of the physical construct of home.

A homeless persons' pride, which is an important part of their identity, is partly based on their construction of 'home,' much as the pride of a home dweller swells when they purchase their home (Hill and Stamey 1990). The self-esteem of homeless people can be boosted by their becoming independent of welfare institutions and shelters. Those who sleep in shelters, in contrast, may struggle to develop their self-esteem because of their dependence on the shelters. Despite the fact that shelters offer basic security and protection from the weather, their invasion of the occupants' privacy and the general loss of control prevent them from functioning as home in behavioral and emotional terms (Hill 1991). This supports the notion that the home is not just a physical location but can also be interpreted as a state of mind or as related to typical behaviors. These findings, however, are not universal: other studies on homeless people present different findings. For example, homeless people in Australia regard housing and home as the same. The physical structure is central to their meaning of home and is considered as a solution to the problems that relate to their being homeless. For them, home is a signifier of normality, and a commitment to participate in Australian society (Parsell 2012). Home behavior is nonetheless apparent in homeless humans and animals, even if this behavior is less marked than home behaviors focused on a permanent physical construct.

8.6 The Territory as Home

Many herbivore species do not have a permanent home site, but rather a well-defined home range in which they rest at temporary sites. For example, wild boars (*Sus scrofa*) usually inhabit a range of two square kilometers. Within this range, they prepare a rest site by clearing and rubbing the ground into a shallow ditch which they use for several days before moving on to another temporary ditch in the territory (Mendelssohn and Yom-Tov 1999). Similarly, adult wild asses (*Equus asinus*) inhabit territories ranging in area from 2 to 20 km^2, which they patrol while vocalizing their ownership and demarcating it with 40 cm-high piles of dung about 1 m in diameter. Within this territory, wild asses rest in the shade of trees or rocks (Mendelssohn and Yom-Tov 1999; Nowak 1997). Similar behavior characterizes many antelopes, rhinos and primates. Another example of a territory as home is the habit human teenagers have of decorating their room in a style that differs from the rest of the house, thereby demarcating their room as their territory and identity within the home. In the subsequent stage, when they leave the parental home and move to, for example, a university dormitory, they make their room there a new home, decorated with their own possessions and ornaments and establish their sense of independence and identity. This process of acquiring home identity is often inhibited in military camps or prisons, where decorating the dormitory or cell may be forbidden. In these institutionalized settings, a bed and small closet become the individual's only source of privacy, emphasizing their identity as soldiers or prisoners, for whom the lack of home is an overt and enforced manifestation of the lack of freedom and independence; the lack of a place where one can be more oneself than anywhere else (Burnard 1999).

8.7 The Group as a Mobile Home

Many herbivore species are social: their herd, once they are in one, is their home. The herds may inhabit a specific living range or migrate seasonally to a remote living range with better resources, whereby the anchor for activity is social, not physical. The behavior of herd individuals is highly synchronous, and they all rest, feed, move, groom, take dust baths, suckle and excrete according to the same schedule (Estes 1991). These behaviors seem to be contagious even across groups, resulting in mass movement, such as the vast migrating herds of the African buffalo (*Syncerus caffer*) or wildebeest (*Connochaetes taurinus*; Estes 1991; Molszewski 1983). The formation of a "social home" has been illustrated in a laboratory setting with juvenile laboratory rat littermates that form a huddle when placed in an arena outside their nest. The young rats then take exploration round trips from the huddle that is their new home base, despite its continuous drifting across the arena when the pups push each other into the huddle (Loewen et al. 2005). In other words, the huddle of littermates—not its location—serves as a home base.

The sense of comfort and safety rendered by the group (Bednekoff and Lima 1998; Elgar 1989; Szulkin et al. 2006) as a trade-off for the need for a physical home reaches an extreme manifestation in the nomadic lifestyle of certain gregarious species. The red-billed quelea (Quelea quelea) is the most abundant wild bird species in the world, with a population of about 10 billion individuals that aggregate in sub-Saharan African savannas (Fig. 8.5). These small birds travel in large flocks to forage, rest and breed according to the resources available (Dallimer and Jones 2002). A similar nomadic spatial behavior is typical in the highly sociable cedar waxwing bird (*Bombycilla cedrorum*) that lives and travels in large flocks in Central and North America (Putnam 1949), and in the Australian wild black swan (*Cygnus atratus*) that gathers in nomadic flocks of thousands, which travel in erratic patterns (Kingsford et al. 1999). A nomadic lifestyle is also seen in some insect swarms, such as locusts and army ants. All the nomadic animal species mentioned above are highly gregarious, and it is probably the power of the group that provides a feeling of home, thereby replacing the need for a physical anchor as a home. A nomadic lifestyle characterizes some human communities, such as those of the Romany and Bedouins, who settle temporarily in one place and then move on to another. It is interesting to note that in Bedouin communities, the tent (which is their home) is divided into two areas, separated by a piece of cloth. One area is the men's area, the other is the women's (Rosen and Saidel 2010). This can be related to the identity of the Bedouin in terms of cultural and religious characteristics.

Fig. 8.5 The red-billed quelea (Quelea quelea). A nomadic African bird that is the most abundant wild bird species in the world

Another example of a social home is that of elderly people who voluntarily leave their own private homes and move to live in a condominium. These projects are not nursing homes nor medical care facilities and they do not offer supervision at all hours of the day. They are designed to integrate the housing and service needs of the elderly with a social life. The goal of these projects is to increase the independence of the community by providing support services. Research showed that the majority of women living in condominiums were emotionally attached to their new residence and considered it home, despite the fact that this housing was not their private property. For them, the meaning of home emerged from their autonomous decision to find a place to live in, combined with the continued decision to remain there (Leith 2006). In other words, for these elderly people the behavioral (non-physical) properties of home were detached from their private home and attached to their current housing.

8.8 Epilogue

There is nothing like staying at home for real comfort.—Jane Austen

While there are obvious differences between humans and animals, there are also many similarities, and this paper has shown that the meaning of home extends far beyond its mere physical construct. First and foremost, home is a state of mind that involves typical (sometimes even exclusive) behaviors that are rarely performed elsewhere. Home is where one is supposed to be most protected and relaxed. Moreover, people arrange and decorate their homes as an expression of their individual identity and persona; there is a firm attachment between the physical construct and home behavior. The home is also a core for the organization of behavior in time and space. It is a hub for traveling within the living range, and people carry out many of their activities on the way from or to home, such as dropping the kids off at school on the way out, or shopping for groceries on the way home. Thus, the home is the core organizer of behavior within the living range. In this context, having a permanent home and traveling methodically along the same routes to the same locations seem beneficial, providing increased efficiency in using the resources available in these territories. Accordingly, home and home range may be viewed as adaptive properties in both humans and other animals. Moreover, home-related behavior is such a robust and vestigial trait that it is preserved even in the absence of home as a physical construct (see the section on “homelessness”). This has also been illustrated in rats, which, when placed in an homogeneous unfamiliar environment, establish a home base in an arbitrary location—usually the point at which they were introduced into the unfamiliar environment—then organize their spatiotemporal traveling in relation to that home base (Eilam and Golani 1989). In summary, home is first and foremost a behavioral phenomenon: a psychological-emotional competence which is manifested in an analogous form in both humans and non-humans. In light of Darwin’s notion that emotions are homologous in animals and humans (Darwin 1998, first published in 1871), and studies showing that there is a continuity of the emotional brain between humans and animals (Dalgleish 2004; see, however, Penn et al. 2008, who claimed that this is a mistake, considering the large gap between animals and humans) it might be suggested that similar biobehavioral systems in humans and non-humans account for the convergence of home behavior to similar traits, as described in this paper. This conclusion is in line with Darwin’s statement that the difference between animals and humans is one of degree, not of kind (Darwin 1871).

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Part III
Complexity, Cognition and Planning

Chapter 9
Framing the Planning Game: A Cognitive Understanding of the Planner's Rationale in a Differentiated World

Gert de Roo

Abstract "Framing the Planning Game" discusses four cognitive features—realism, relativism, relationalism and idealism—and their mutually supportive relationships. When taken together, these help understand a multitude of realities: a factual reality (realism), an agreed reality (relativism) and combinations of these two realities (relationalism) between the two extremes. An endless variety of combinations results in a differentiated reality, allowing the planner to consider every situation generically as well as specifically. We call this a *differentiated world view*. These various realities can be seen as a-temporal as well as directly related to desired futures (idealism), meaning that a differentiated understanding of the 'planning game' includes transformations caused by both time and non-linear processes. Such a flexible imaginative frame enhances the planner's vision, allowing them to embrace contemporary planning ideas while including a non-linear understanding of situations as inherently unstable and dynamic, a reality that all planners recognize but few integrate in planning.

9.1 Planning and Cognition

Contemporary planning considers realism and relativism to be the frames of our cognitive understanding. In this contribution we have strong reasons for expanding these two cognitive frames to include relationalism and idealism. In this chapter we elaborate on the consequences to the discipline of spatial planning if its world view were to relate to four rather than two cognitive frames. One of the consequences

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would be a fundamental transformation of planners' perspectives on their environment. Traditionally, the planner has a strong focus on the here and now. The planner either builds on the certainty of facts (the consequence of a realist perspective) or tackles uncertainty through agreements by consensus (framed by a relativist understanding). This has caused planners to have a dual perspective on reality: a factual reality and an agreed reality.

Introducing relationalism implies regarding reality as neither factual nor agreed, neither black nor white, zero or one, 'yes' or 'no.' Instead, relationalism would mean considering an infinitely variegated universe of realities between the factual and the agreed, introducing a differentiated world view. It is all a matter of degree, as we will see in this chapter. Realism, relativism and relationalism frame the world as it 'is,' a-temporally framing of our observations.

With the introduction of idealism, time becomes explicit: the world not as it 'is,' but as it is 'becoming.' Idealism frames the world beyond the here and now: it presents us with the world we can imagine and desire, a future world we might want to reach for. Thinking through the route towards this ideal future, we can no longer assume a clear, well defined and linear path, which is the implicit assumption of realism. With idealism and becoming explicit about framing the future, non-linearity cannot be ignored as a phenomenon. A non-linear perspective focuses on a world that is continuously becoming, full of uncertainties and with limited room for control. This world of becoming also generates possibilities, provided that the planner is able to identify them. While this might not be easy, it may well be more realistic than a dual reality built on either facts or agreements.

It should go without saying that expanding the planner's cognitive frames by also considering relationalism and idealism should not be a retrograde step. Instead, it should improve our capabilities in understanding reality and dealing with it. Introducing a differentiated world view encompassing non-linear behaviour could be a major step forward for the discipline of spatial planning.

We believe it opens up existing but previously undisclosed realities. Rather than getting lost in all these realities, we will explore alternative (if not better) understandings of the world we are part of. Our discussion concludes somewhat surprisingly with the idea that planning theory itself can be viewed as a *pattern* of idealist thought. As such, it behaves as an order parameter, a power law, an attractor and as a convention that we implicitly or explicitly acknowledge as being the way it should be, and act accordingly.

9.2 A Dual Understanding of Reality

Realism considers the world as 'out there,' full of objects with implicit, embodied meanings independent of our being conscious of them. Realism relates to the world that 'is'. In the early twentieth century it was thought that the world could be expressed 'objectively' with facts and figures (Nozick 2001). As such, an assumption was embraced that this world which 'is' could be fully comprehended, given time, effort and capacity. This realism relates strongly to a Newtonian world view in which reality is ideally uniform and shows cohesion and order: Reality can be revealed in universal (orderly) laws to which the world conforms. A world working according to Newtonian reality would be full of direct causal relationships: mechanistic and functional.

Planners in the early twentieth century were strongly attracted to the concept of functionality (Faludi 1973; Meyerson and Banfield 1955; Tugwell 1932). In the fifties, sixties and seventies it became the cornerstone of their planning principles, in conjunction with concepts such as minimization, standardization and equality. This strictly functional perspective on the world was increasingly criticized in the late twentieth century as being 'emotionally hollow, aesthetically meaningless and spiritually empty' (Pirsig 1974). The rapid rise of critical realism can be seen as a response to this critique, which today is supported by most realists. Critical realism accepts that the world which 'is' is only partially perceived and socially constructed (Sayer 1984; Yeung 1997).

Relativism refers to worlds of meanings resulting from people developing, exchanging and incorporating mentally constructed values (Habermas 1995; Rorty 1991). While realism stresses a relationship between the subject and the object, the relationship between subjects is central to relativism. Relativism is about the world of subjects exchanging their mentally constructed ideas, values and opinions about the world of objects and how this world of objects should be interpreted. Intersubjectivity is therefore central to relativism: interacting subjects exchange their constructed values, opinions and stories, and attempt to make sense of these together, potentially leading to consensus on how to view the world (Lakoff and Johnson 1980; Nozick 2001). Relativism explains the emergence of culture and attitudes—both traits that are essentially shared by a group—and is key to understanding social behaviour and social values.

In the nineties, the planning discipline experienced a paradigm shift known as 'the communicative turn' (Dryzek 1990; Healey 1992). This turn is a shift in focus from an object-oriented type of planning to intersubjective interactions. It included the acceptance of a world which could no longer be regarded as fully certain: facts were no longer viewed as the only route to understanding reality. Reaching consensus became a valuable additional route to determining reality collectively, as it leads to agreements. Agreements became a welcomed concept to tackle uncertainty. Agreements about how to view the world are the result of shared ideas and consensus. Uncertainties can be transformed into certainties on the basis of agreements: not factual but agreed certainties. The consequence of this reasoning is fundamental: both factual reality and agreed reality matter!

As such, we have clarified why realism and relativism matter and are both parts of the planners' cognitive frame (De Roo 2003; De Roo et al. 2012). Both represent essential understandings of a reality produced by the human brain as an iterative, self-referential process of awareness relating the world of objects and the world of intersubjects, at once checking and balancing, reinforcing and debilitating, and constructing, deconstructing and reconstructing processes of the self, the other and the environment. We will see in this chapter how this process of conjunction of the real and the relative supports spatial planning and decision-making processes.

To bridge a factual and an agreed reality with planning, decision-making and a proper or suitable institutional design, contemporary planning essentially builds on two rationales: technical and communicative. The technical rationale is framed by a realist perspective and neo-positivism, which incorporates the promise of certainty being within reach (Faludi 1973, Friedmann 1987). Decision-making processes within this realm focus closely on the facts available at the moment of decision. The *modus operandi* is that the effect of the decision can be known in advance and therefore taken into account. Accordingly, various steps of direct causal interactions will follow, ending in a situation or result that was expected to become real at the time the decision was made. Decision-making based on a communicative rationale aims for consensus between all the parties involved (Innes 1995). The communicative rationale is framed by a relativist perspective and by constructivism and all this incorporates. The parties involved are expected to have more or less equal vested interests they have in the matter, although the nature of the interests themselves will vary. An agreed reality transforms uncertainty into certainty and brings certainty back within reach. These two cognitive frames and their rationales seem mutually exclusive and are responsible for a dual attitude within spatial planning.

Within the contemporary planning debate there is an awareness of a realist and a relativist cognitive frame (Allmendinger 2009). A realist perspective offers planners a technical rationale through which to frame the world based on object orientation and the observation of facts: it is the planner's traditional rationale which is the technical rationale. Planning took a 'communicative turn' in the nineties. This communicative rationale emerged from and represents a relativist perspective: the world of intersubjective interactions and the exchange of values resulting in commonly agreed realities (Sager 1994). Both cognitive frames have been crucial to planning and its development. We argue that there is more.

We will continue the argument that relationalist and idealist perspectives are also relevant to the planning discipline (De Roo et al. 2012). A relationalist perspective enables us to see the world in degrees and allows us to differentiate situations in subsequent categories of planning issues (from small to large, from simple to very complex). An idealist perspective also refers to imagined worlds, worlds perhaps desired as statements of what is to be achieved, stressing the importance of becoming. We reason that these two cognitive frames support the planning discipline by considering a differentiated world view, both rooted in the here and now (relationalism) and with regard to time and imagined futures (idealism).

9.3 Facts and Stories

Are situations representations of a realist, factual world, or should these situations be regarded as relative, constructed facets of a world that is agreed upon? How should spatial situations be considered with regard to this duality? In practice, planners pragmatically combine both perspectives when observing, responding to and interacting with their spatial environment. A realist perspective dominates when the spatial situation is accompanied by implicit certainties and a common understanding of the situation at hand. A relativist perspective leads in situations which are fuzzy, fluid and vague, and where an implicit understanding among those involved is lacking. In such cases, a communicative process should unfold to facilitate the consensus required to proceed. This attitude of pragmatically combining the two worlds has been quite successful. It has resulted in the definition of a diverse set of recurring planning issues, to which a set of well-defined approaches, actions and planning behaviours relate.

This attitude is theoretically inspiring for us because it relates to *a differentiated world view* (De Roo 2003, 2010; Zuidema 2011). It recedes from the idea that the world we are part of 'is,' responding to universal rules through which the world can be 'fully' understood, if only we allow ourselves the time, money and energy necessary to become aware of all the essential facts. This certain, unalterable factual reality is no longer the 'single true world' that surrounds us. Nor is the communicative world of agreements—with all parties happily interacting to reach an attainable consensus—the only valid perspective. This agreed reality might be desirable for its capacity to satisfy the various interests at stake, but it could be a reality removed from what is actually happening. In contrast, a differentiated world view accepts that (1) situations are a mixture of certainties and uncertainties, and of facts and values, and (2) situations are individually perceived and perceptions differ between the parties involved. These individual perceptions and constructs can be shared to attain common understandings with others about how to understand situations and how to respond to them.

The framework for considering a diverse and differentiated world is a major step in our reasoning. Every one of us might be able to differentiate between clear and fuzzy situations, and in the realm of spatial planning the interaction with other subjects (parties or stakeholders) is crucial. Through mutual interaction we build grand ideas, discourses and paradigms about how to see the world and how to respond to it.

Consequently, we have now constituted various (if not endless) realities between two theoretical extremes, one that relates to a world in which 'certainty' prevails and in which a technical rationale can be followed to reach a desired 'end,' and a second extreme in which situations are made uncertain by the competing interest of numerous stakeholders and a fluid mix of functions and structures: In short, and a sense of the situation being 'fuzzy' (De Roo and Porter 2007). We argue that these two worlds which are seemingly opposite extremes of a continuum within which there are a diverse set of (real) situations and planning issues. By combining both perspectives planners are better conceptually equipped to address situations in practice. We can frame these practices theoretically by positioning them on a spectrum between technical and communicative rationales. We call this the planners' *holy spectrum* (De Roo 2000, 2003).

One end of the spectrum is the technical rationale in its purest form. It is above all a theoretical position, not encountered in the empirical world. It is a crucial position nevertheless, enabling the understanding of situations which are themselves less clear and certain. On the technical rationale end of the spectrum there can only be one true world, clear and well defined in every possible way. This one true world is synonymous with perfect certainty. Collecting facts is imperative, as these are the building blocks of this certainty. From this realist perspective, the more facts we gather, the more complete the world will become, and the more certainty is gained, the better we understand reality.

From a governance perspective, this would mean that a single body of power is likely to oversee how its decisions develop at every level of implementation. This requires a coordinative government with a command-and-control approach, developing routine procedures and producing predefined outcomes (Faludi 1973). Moreover, planners in the 1950s and 1960s, having adopted the perspective of a certain world quite seriously, are eager to invest in collecting information to increase certainty. The result is a blueprint of the shortest route to an ideal outcome.

The other end of the spectrum is the communicative rationale, representing a world full of uncertainty. It is not a postmodern world in which we doubt all the information we encounter. Late-modernism is a better term for it (Harvey 1990; Jameson 1984). We consider late-modernism to be a perspective which accepts fundamental uncertainty, but which nevertheless can address it through intersubjective interactions. This correlates to relativism. Such interactions are meant to achieve joint agreements about the uncertainties which have to be dealt with.

Intersubjective interactions result in commonly accepted storylines. These storylines frame uncertainties, as they are carriers of proposals which overcome these uncertainties in support of further actions. Uncertainties are a trigger for groups to begin discussion and a leading reason for interactively reaching a common agreement which enhances a situation. The planner's task here is above all to bring people together, enabling them to share ideas and information, and understanding individual input as essential to reaching a common understanding of the situation at hand: the planner mediating between the various parties to help them develop then accept one storyline in common with which to frame and tackle the shared uncertainty in question.

While in a technical rational environment goal maximization is the ultimate task for attaining predefined 'ends,' at the communicative end of the spectrum the focus is on process optimization and agreement by consensus. Consensus is about defining the issue and sharing responsibilities in dealing with it. Shared governance is the *modus operandi* here, rather than command-and-control. In this mode, the government is no longer a coordinating body but rather a facilitating one. The focus is less on routine, such as a procedural protocol, than on the specifics of the situation and its contextual environment, and the stakeholders grouped around this

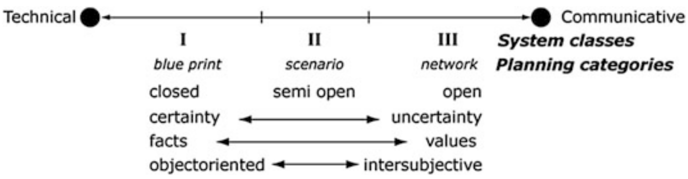

Fig. 9.1 The holy spectrum of spatial planning (De Roo 2010)

situation are likely to shoulder a major part of the responsibilities. Since the communicative turn in planning, uncertainty has been considered as real and as fundamental as certainty to the planning process. However, the communicative rationale is an extreme that cannot be found, in its purest form, in reality. But it remains vital; having a clear picture of this theoretical end of the spectrum can help us to work out how to address any situation between the two extremes (Fig. 9.1).

9.4 Along the 'holy spectrum'

If we take a closer look at the *holy spectrum* to think through what it represents, we discover that it offers a rather peculiar combination of rationales. These give expression to varying proportions of initial certainty and uncertainty. Technical rationale gives expression to the certainty-uncertainty ratio in a fundamentally different way than the communicative rationale does. The first is object-oriented, it builds on the world of facts. The second relates to intersubjective interactions and values the world as it is perceived. At first glance it seems these two rationales and the way they explain how to understand the world are separate and do not meet, as illustrated by Fig. 9.2a.

We believe the two rationales relate contingently to each other because the relationships between realism and relativism and between facts and value are contingent. To be more precise: we see a contingent relationship between object orientation (facts) and intersubjective orientation (values) in relation to reality. This contingency starts at a point where situations are perceived as undisputable factual

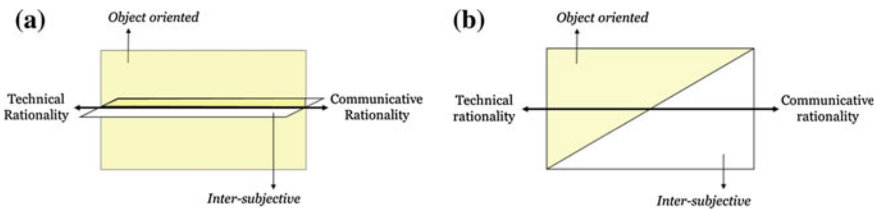

Fig. 9.2 Framing the duality of planning: crossing (**a**) and by ratio (**b**)

realities which do not require further clarification (or 'agreement') by inter-subjective interactions. Situations perceived with such certainty are positioned at the far left of the spectrum and are consequently strongly object-oriented. If we turn to situations which are increasingly uncertain, we observe a shift in attention: Object-oriented interest diminishes while inter-subjective interaction becomes increasingly relevant, as illustrated by Fig. 9.2b. Consequently, the spectrum between the two extremes of perceived certainty represents both the changing ratio between certainty and uncertainty along it and the existence of a continuum from object orientation to intersubjectivity.

A shift from left to right (which is a shift from certainty to uncertainty) on the spectrum also means that conditions expressed with a technical rationale become implicit while those expressed with a communicative rationale become increasingly explicit. However, a *contingent* relationship means that the two interwoven routes to becoming informed about the world—object orientation and intersubjectivity—do not just change proportionally with respect to which of the two routes is the most dominant: Both routes also change in character as they move along the spectrum.

The leading characteristics of the object-oriented perspective—direct causality, clear entity and a stable context not interfering—relate to the technical rationale (Fig. 9.3a). These qualify facts and a strictly factual world. In situations in which technical rationality prevails, only direct causal relationships are taken into consideration, making any movement or change predictable. Entities stand out clearly from their context, which becomes irrelevant as it in no way interferes with its factual identity. Yet in an uncertain world—in a diminishing technical rational environment—we are no longer able to see less clearly if at all direct causal relationships. Instead, we are confronted by relationships which exhibit remote causalities; entities are no longer explicit but fuzzy, fluid, vague and undefined, partially due to the difficulty in distinguishing them from their context which is itself unstable. Emery and Trist (1965) qualify this discontinuously situationally interfering context as 'turbulent fields' (Fig. 9.3b).

Although in sharp contrast with the logical-positivist reasoning of technical rationale and its promise of certainty, it is not hard to imagine the relevance of a fuzzy situation to its characteristics: It opens causality, entity and context to debate (see Fig. 9.4a). While a fact represents a clearly defined world, a debatable world

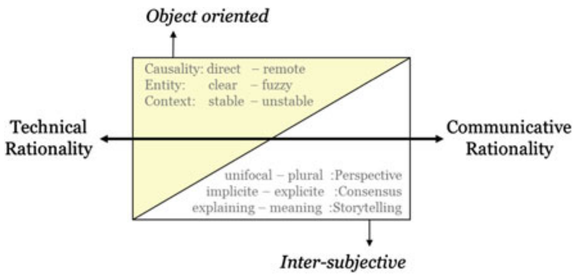

Fig. 9.3 The framing conditions of the real (object-oriented) and the relative (inter-subjective)

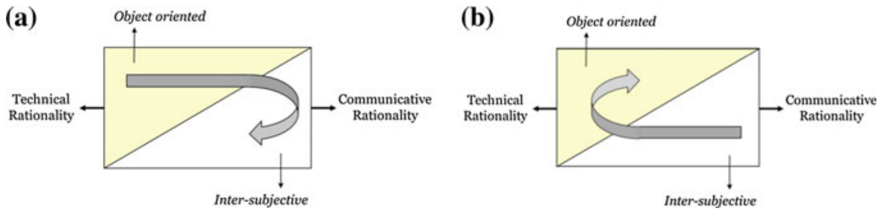

Fig. 9.4 The inevitable advance from one orientation domain to the other, with decreasing (**a**) and increasing (**b**) certainty

needs agreements to make it collectively comprehensible and equivalent about how to view the situation. According to a communicative rationale, the parties viewing a fuzzy situation will have varying perspectives and ideas about it. The resulting idea, storyline or discourse—held in common—colours the situation from various angles and connects facts and factors, values and actors.

Intersubjective interaction is central to reaching agreements, consensus and a shared storyline. Interacting actors (subjects) are characterized by a desire to find common ground—a shared value, opinion or meaning about a very complex world—which makes sense of situations multiple parties are facing. Such an agreed reality is based on three characteristics: each actor's individual starting perspective, a consensus achieved among them all, and a clear picture (story) of this shared understanding (Fig. 9.3a).

These characteristics change as the situation becomes simpler and more straightforward. This would mean, primarily, a shift from multiple or plural perspectives to a univocal view of the world. While a highly complex world needs explicit agreement among all parties on how the world can be understood collectively, the agreement becomes increasingly implicit as the situation becomes clearer. The story composed to enable all the parties to have a shared understanding and to give meaning to the situation increasingly speaks for itself as it is gradually regarded as what we consider a 'fact' (see Fig. 9.3b). Moreover, instead of giving meaning to the situation, it will become a base from which explaining the situation begins to make sense. Again, this means we have returned to a technical rational environment (Fig. 9.4b).

Stories are essential for us to understand reality: not all facts are fully comprehensible, nor are we in a position to collect all possible facts. Stories deal with this deficit; through stories, facts are contextualized and acquire meaning. Facts and stories are two sides of the same coin. Taking this further, from a communicative rationale perspective facts *are* stories, although a very particular type: stories expressed by the characteristics of a technical rationale. Facts and the technical rationale that frames them are essential to stories, as these represent the immediate connection with the world surrounding us. In other words, the relationship between facts and stories is fundamental.

9.5 'A Matter of …'

Facts and stories are both essential expressions of our reality. These expressions are valid under conditions which are very much part of both the technical and communicative rationales. The technical rationale connects with the object, entity, event or situation itself: the perceived material world. The communicative rationale is about what we think of these manifestations: the mentally valued world. Conversely, communicative rationale allows us to discuss the possibility of an external reality and technical rationale allows us to locate it, touch it and interact with it.

There is an interdependent relationship between the two rationales. If the conditions for a technical rationale are rendered hopeless by a situation of total fuzziness, agreements about how to view reality can facilitate a common understanding: a factual world is replaced or supplemented by an agreed reality after the agreement is reached. Under these circumstances, a communicative rationale would consider the technical rationale perspective and the consequence of a storyline representing a 'one true and certain world' framed by particular conditions.

We have discussed in depth the essence of both rationales, the two world views they represent and the conditions under which these rationales frame the world. We have also seen these conditions change according to the contingent relationship between the two rationales: across our *holy spectrum*, an object-oriented focus is replaced by intersubjective interaction as the situation becomes increasingly uncertain. With this replacement, a shift in conditions deduced from both the technical and communicative rationales must be taken into consideration. This is how our *holy spectrum* (see Fig. 9.1) gives expression (explanatory power and meaning) to the world as we perceive it.

We have introduced our *holy spectrum* as a representation of *a differentiated world view*. Our reasoning started with reference to realism and relativism, followed by a proposal to bridge the two. We have also been constructing a world of infinite realities between them. This allows us to consider every situation as unique and specific under clear, predefined and generic conditions which relate to both rationales (see Fig. 9.3). The two rationales and the sliding spectrum between them allow us to position any situation 'precisely' by category at a given point on the spectrum. As these clear, predefined and generic conditions produce a contingent relationship between a situation and the mix of rationales which relate best to it, a planning approach, the action to be taken and its result, will become clear a priori (from a meta perspective, clearly not in detail). Despite the situation's uniqueness, it is *relational* to the two extremes and to other situations allocated on the *holy spectrum*. Therefore, aside from the real and the relative, a situation can be expressed in relational terms (Boelens 2009; Emirbayer 1997; Hillier 2007). The relational is another cognitive route to understanding our reality: relationalism.

The planner's *holy spectrum*, framed by technical and communicative rationales, has strong links to the systems world view. Systems theory differentiates the world broadly into three major categories (Kauffman 1995; Langton 1992): closed, circular and network systems. All three systems categories are relational to each other. However, each category introduces specific consequences. Closed systems, also known as Class I systems, represent a certain world of nodes and interactions. All nodes are specified, including how these nodes operate and relate to each other. Knowledge is based on knowing the nodes, their functions and their links to each other. Class II systems incorporate feedback mechanisms through which the projection of an assumed result or outcome of interacting nodes (i.e. a possible or likely future) can be tested, and adjusted as assumptions are proved wrong. Class II systems are also known in the world of planning as scenarios or projections. Open systems are Class III systems. These function as networks within a wider and interfering environment. While closed systems are considered as having no interaction whatsoever with their environment, network systems—or open systems—are in a continuous state of reacting to impulses, actions and information coming from outside their contextual boundaries. Instead of gaining knowledge by knowing the nodes' identity and behaviour or structure and function, knowledge in open network systems closely relates to processes of communication and interaction. These systems have an attitude best explained by a communicative rationale.

The system classes suggest a continuum from one extreme to the other, categorizing a world in between the two extremes (De Roo 2010). This world in between has its equal in planning: blueprint planning relates to a closed systems environment in which we assume certainty to be dominant. Scenario planning relates to circular systems with feedback mechanisms. At the time that scenario planning was introduced in the nineteen-seventies, it was not considered part of a spectrum. On the contrary, it was seen as an apology by planners for not being able to fulfil the promises of the technical rationale. Taken as a second best approach, its rationale was thought of as being constrained by time, money and energy: a bounded rationale. From today's standpoint, this 'verdict' belongs to a simplistic past. Instead, we are increasingly acknowledging scenario planning as a proper means to address a reality positioned between a certain and uncertain world. Open planning approaches relate to network systems, which became popular during the 'communicative turn in planning' in the early nineties.

Embracing the communicative rationale in planning, many felt the technical rationale would fall out of use, a relic of the past. This is doubtful, as there remain situations a planner would prefer to control in full, instead of including them in a communicative process aimed at reaching consensus. The introduction of the *holy spectrum* clarifies that the technical rationale is neither dated nor outdated, but rather situation specific. In situations which are stable, certain and straightforward, a technical rationale is preferable. Situations which are uncertain, fuzzy and located in an environment which continuously interferes favour a communicative approach. Most issues exist between these two positions.

The consequence of this reasoning is that we can easily identify three categories on the *holy spectrum*: simple, complex and highly complex situations (see Fig. 9.1). The contingency which dictates the *holy spectrum* of planning relates to degrees of complexity. It is a *static kind of complexity*, qualifying a situation as it 'is' in the here and now (De Roo 2010). This is distinct from a dynamic kind of complexity, central to the complexity sciences and defined by situations which are perpetually 'becoming'. Static complexity, as embodied in the *holy spectrum*, considers a situation as fixed or frozen in time, and locates it on the spectrum according to its degree of certainty and a compliant mix of facts and values. Considering reality as 'a matter of degree' qualifies situations as specific within a generic frame. In other words, situations are seen as part of *a differentiated world*.

Relationalism addresses a world in which objects (such as events and situations) are understood in relation to other objects. Here, relation can be measured in terms of degrees and by its position relative to—or in interdependency with—other objects. A 'matter of position' can easily be explained by reference to a piece of wood on four legs, which has to be considered 'a table' because there are chairs around it. A matter of degree is equally easily explained by reference to sequences such as 'small, big, massive,' 'village, town, city, metropolis,' 'cabin, house, palace' and so on. Our differentiation of planning issues as simple, complex and very complex relates to this same 'matter of degree.'

The *holy spectrum* is relationally divided into categories. These categories are considered simultaneously through the cognitive frames of realism and relativism. Relationalism relates to realism as it regards objects, events and situations in relation to other objects, events and situations. We have observed a contingent relationship here, incorporating a shift from direct causal relationships between clear entities in a stable environment to remote causalities between fuzzy parts in a dynamic environment. A relational perspective adds *information* to objects, events and situations by comparing these with other situations.

Relationalism also relates to relativism; when a situation is 'fuzzy,' it is for those involved to mutually agree on how to view, value and weight the objects, events and situations. This mechanism of mutual agreement incorporates an element of *choice*: how to define the situation at hand. It is an individual choice to consider, balance and weight the ratio between certainty and uncertainty regarding a situation. The choice is also, in part, a communal choice: The actors involved discuss the relevance of what is known and what is unclear, and based on this decide which related approach, action and consequences best fit the situation. Having said this, we must consider that not only the various factors but the actors may be 'unclear': not all actors are willing to take responsibility, and some may even obstruct the planning process.

Contingencies are traditionally seen from a realist and object-orientated perspective on reality. With regard to the *holy spectrum*, we cannot ignore the presence and the relevance of relativism and consequently the intersubjective element of choice. Zuidema (2011) qualified this relational understanding of the *holy spectrum* as *post-contingency*.

This differentiated set of well-defined planning issues has a post-contingent relationship with its elements. Planning issues as they 'are' (realist perspective) or as they are 'agreed' (relative perspective) can be understood not just because of their intrinsic qualities but also according to their relational position on a spectrum of planning issues. This relationalist perspective has two aspects, both of which are fundamental. One is to consider every planning situation as a combination of a factual and an agreed reality; every planning situation can thus be positioned on a spectrum between the two absolute, with both of these present to some degree.

We consider these possible and altering combinations of a factual reality and a reality of agreements as a meaningful response to the acknowledged duality in planning. The other fundamental aspect of a relationalist perspective is a shift from a determined and dual view of planning (either functionality and a 'one-size-fits-all' attitude or considering only two opposing planning realms: the factual and the agreed), to a differentiated one.

The spatial planning discipline beds most of its theoretical reasoning in the cognitive understanding through which realism and relativism are related. Etzioni (1967) never explicitly referred to relationalism. However, his mixed scan approach relates strongly to it: 'Reality cannot be assumed to be structured in straight lines where each step towards a goal leads directly to another and where the accumulation of small steps in effect solves the problem' (Etzioni 1967: 389). Mixed scan proposes a two-step approach to understanding reality: a wide and generic understanding strongly influenced by situational context; and a narrow and specific understanding which digs deep into those parts considered relevant to the situation. The parts, the whole (the situation) and its context acquire meaning through being considered meaningful in relation to each other and are therefore relational.

Recently, some writers (Hillier, Van Wezemael, Boelens, Boonstra, De Roo and others) have begun to make explicit reference to relationalism and spatial planning. Hillier (2007) refers to the poststructuralists Deleuze and Guatari when exploring the situatedness of planning issues: For them as for Hillier, situations are proposed as assemblages—material manifestations of components which merge with or deviate from each other repeatedly—in a process at a particular place and time. This is also referred to as situations being 'historically contingent'. Van Wezemael (2008, 2010) favours DeLanda's situational understanding of reality, stressing the heterogeneity of the world of components, and the relationship between an assemblage (a whole) and its components (the parts) as complex, non-linear and self-referential.

Recently, planners have taken a strong interest in the work of Latour (2005) and Actor Network Theory (Callon 1995; Law Law 2004). Actors or agents acquire meaning in and through collectives. For Latour, 'participants explicitly engage in reassembling the collective' (2005: 247). Consequently, reality is considered as the product of collective behaviour. Actors interact within this reality which they have been instrumental in creating, or, in other words, in which actors are relational. Boelens (2009) takes this reasoning further to construct what he calls the *Actor Relational Approach*: 'In order to analyse a particular space or spatial question, we must follow the actors or stakeholders and the networks of relations that they form. Thus, relational planning does not consider a plan or a project as the focal point when it comes to spatial developments, but the actors' (Boelens and De Jong 2006: 111; Boonstra and Boelens 2011).

Some contemporary scholars (De Roo 2003; Rauws and De Roo 2011; Verhees 2013; Zhang et al. 2012; Zuidema 2011 and others) already embrace the idea of a differentiated world view, classifying planning issues on the basis of their complexities. First, planning issues are weighed up based on their internal and static complexities, which relate to the contingent and post-contingent relationships between the technical and communicative rationales through which classes of planning issues connect to specific planning approaches, actions and consequences. Secondly, planning issues are measured by their internal-external relationship and their dynamic complexities, building on the idea of the world undergoing a continuous process of discontinuous change, open to non-linear developments and resulting from co-evolving and transformative processes in time. In this chapter, we started building on this notion of static complexity and contingency to explain the role of the various cognitive understandings commonly applied to spatial planning. By incorporating 'dynamic complexities' as part of a differentiated world view we continue our reasoning going beyond the here and now.

Before we start deliberating on the issue of time and the becoming, and the dynamics that come with it, we have to bring our reasoning regarding relationalism to a proper end. The various categories of planning issues can be viewed as contingent and post-contingent products (facts and values) which acquire meaning from a realist and relativist cognitive frame. Here, relationalism does not deny or compete with realism and relativism. Instead, relationalism relates to both and builds on them. We consider a static perspective on complexity to be merely one more step towards a dynamic perspective on the same thing: a world that is 'becoming'. This dynamic complexity is relational to order and chaos, and a world 'becoming' desires a cognitive frame on reality: 'idealism'.

9.6 A World of Ideas

No one is able to absorb all the facts that surround us, neither are we able to value every fact or situation comprehensively. We select, and we make sure our selection (analysis) fits well within the story (synthesis) through which we construct a context to a fact. This context connects the fact to the bigger picture, a conception of reality created out of fragments and layers. These fragments and layers combine to form a mosaic of conceptions of reality. This mosaic keeps us quite busy looking for matches between mentally constructed ideas and the externally perceived signals which relate to our constructed ideas. But we have some help doing this: The *holy spectrum* presents us with a rational frame of reference for regarding a world that 'is'. It is also a first step when considering ideas, specifically ideas which relate to the contingency between the technical and communicative rationales.

This imaging of a contingency between the technical and communicative rationales resonates to some extent with a traditional scientific approach to grasping reality: assuming interdependence between analysis and synthesis. *Analysis* is the deconstruction of a 'whole' into its functional parts: a technical rational approach. It is a reductionist attitude which helps us understand the 'whole' by understanding its constituent parts, provided the assumption that certainty is intrinsically accessible among the interacting parts. As if the implicit meaning of the parts are revealed. This revelation is a stepping-stone to understanding the whole 'better': the whole according to the conditions of a technical rational perspective.

The reconstruction of the parts back into a whole is known as a *synthesis*. It is the construction of a storyline in which the parts (as facts) participate as actors would in a play. According to a communicative rationale, the storyline explains and gives meaning. In an uncertain world, a storyline is the conceptual frame that gives meaning to a situation. The frame will position, connect and value the facts coherently with regard to that situation. In a world full of certainty the emphasis is on explaining, by reference to the facts and their direct causal interactions. Consequently, in a world of certainty, analysis explains the situation as it is, implicitly producing the synthesis, while in an uncertain world the synthesis gives meaning to the analysis.

While analysis means exploring a situation to find the parts that make up the whole, synthesis conceptualizes the parts and the whole (preferably within a context). Analysis and synthesis both tie together facts and stories, and we argue that both are intrinsically related and needed to understand reality (see Fig. 9.5a). A clear entity which relates to its parts through direct causal relationships in an environment that is completely stable is an *idée fixe*: such a situation can only be created under extreme and ideal conditions. However, this is not how reality 'works' (or rather, 'is'). When a situation is not entirely ideal (and no real situation is), gaps will appear among the facts we perceive, limiting the possibility of an object-oriented route to knowledge. These gaps will always be present, and widen the moment uncertainty creeps into the observation. In order to bridge these gaps we must mentally construct the possible outcomes, thereby bridging uncertainty in this mental process. When analysing a situation, we always have to imagine. To do so, we employ facts—the building blocks of our imagination—generated through an analysis-synthesis mechanism. These building blocks, both facts and stories, allow us to idealize the situation. Doing so, we take these building blocks out of the context of a reality that 'is' and introduce them to qnd make them part of a world the might be. *Idealism* is the construction of an idea, a concept or a vision about how the world could be seen: a world of ideas.

Intersubjective reasoning is the process that connects the various individual imaginings as explicit constructs of what we observe. It also combines perceived objects with meanings, leading to an understanding of reality. Through object-oriented and intersubjective reasoning, a process of mental interactions starts. In situations relevant to spatial planning, most objects, events or situations are no longer considered completely clear or to have clear and implicit meanings. Instead, we are forced to explicitly superimpose an agreed meaning onto a fuzzy object, event or situation. This fuzzy element and the meaning that we add to it are both greatly interdependent and intrinsically connected, as—once mentally paired—we expect both to match, to relate or to work well together. We call this the *associative* match.

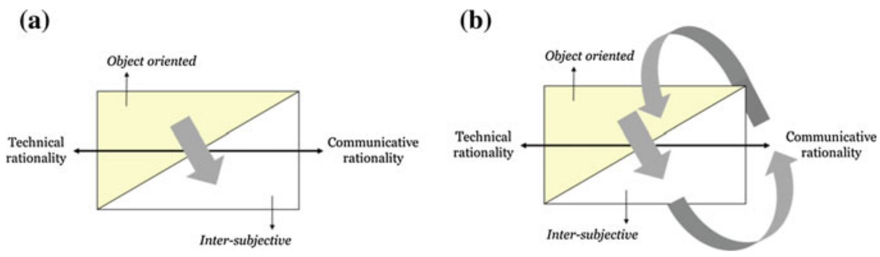

Fig. 9.5 The 'it', entity or idea (**a**) and the self-referential process of imagined possibilities of what can become of 'it': a possible future (**b**)

In planning, the associative match is essential. This becomes clear if we consider the 'object' (or event or situation) as synonymous to structure, and 'meaning' to be the same as 'function'. In planning, we continuously try to match spatially related structures and functions. Where there is a need for housing development due to demographic pressures, the function is clear (to house) and needs a suitable structure (housing). In this case, the suitable structure is likely to require a street plan and various other networks, such as the sewer system and a connection to energy sources or the drinking water supply system. This matching of structure to function is set out in a local plan before it is realized, to allow others (the community, the water board) to share their ideas about it. If there is consensus, the plan will be carried out.

The associative match mechanism is not limited to linking a 'real' object and its 'relative' meaning perceived in the here and now. It also relates imagined realities to proposed, plausible or assumed meanings related to them. Our imagination allows us to play a mental game (in operational terms this is called a 'design'), through which we are able to construct various possible realities, and label them with various meanings: a piece of wood on four pillars could be characterized as a table, which we could also imagine as a drawing board or a bed. But, from the same elements, we can also imagine realities distant from the idea of the piece of wood as a table. Translating the metaphor of the 'table' into planning parlance, we would label the various possible realities as desirable and realistic in terms of the attainment of a possible plan bridging the here and now with a possible future. As such, an associative match could result in a possible creation of something not before considered: this process is what we call *creativity* (see Fig. 9.5b).

Idealism no longer relates to what 'is', but to what might be or might become: the imaginary (Fig. 9.5b). Humans can imagine, and therefore they can imagine a better world: a goal in its own right and one spatial planning is meant to contribute to. Spatial planning considers the world as it 'is' (the actual) and relates this to a world that is 'becoming' (the desired, or ideal—see Fig. 9.6). Spatial planners often call the product of such an exercise between imagination and desire a *plan*.

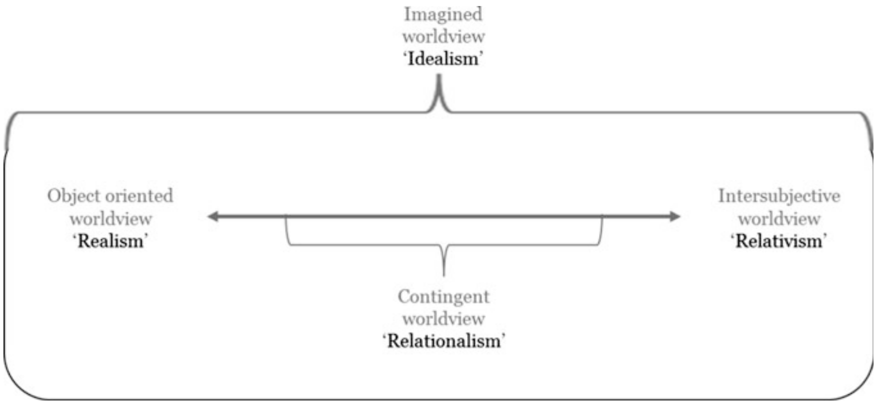

Fig. 9.6 A cognitive frame for spatial planning, bridging the here and now (real, relative and relational) with the imaginary (ideal)

9.7 What if, then …

A plan with proposals for identifying or enacting a desired future will relate to situations and stories, and to the facts and values perceived, constructed and qualified in the here and now; this desired future is connected by associative and creative processes to a reality to become. As there are different perspectives on reality, and as we have the choice to consider reality as it 'is' as differentiated—for example, qualifying it as simple, complex or very complex—every plan will differ in how it addresses a possible future. And each plan will address a variation on a future: it is a vision. The choice of how to view the issue in question conditions the issue and the planning actions which follow. If it is regarded as simple, a blueprint plan will ensue. If it is regarded as highly complex, the plan will be expected to generate discussion. The choice is by and large situationally dependent and will encompass the expected consequences of the actions to be taken. A planner's task is elaborating choice and situation, imagining the possible consequences of the actions taken: "*What if, then* ..." is the logic that follows from *a differentiated world view*. "*What if, then* ..." also refers to expectations, the future image, the idea … the plan.

The plan links the world of rationales with the world of design. The mechanisms we have addressed above (rationale: analysis—synthesis; design: associative—creative) are relevant to planning and various other related disciplines, such as urbanism, urban design, landscape architecture and architecture. While most of these disciplines focus primarily on spatial design, spatial planning relates strongly to both spatial and institutional design. Linking rationality with design allows us to reason differentiatedly about design. But it is also specially relevant to planning because a rationale (at least the technical and communicative rationales) does not address change, development and progress, while design clearly does, being an expression of a desired becoming.

The self-referential mental mode of our associative brain allows us to be creative in looking beyond what we perceive in the here and now (Fig. 9.5b). Making use of the ingredients produced by an analysis-synthesis mechanism, the associative-creative mechanism is able to construct an imaginary reality: the 'it is' is being transformed into a possible 'becoming'. Various methods support this transformation: extrapolation, divergence and convergence, reverse reasoning, connecting trends and scenario construction. These are some of the common methods which can create the conditions essential for the technical and communicative rationales (see Fig. 9.3b). In other words, these methods relate to conditions under which we understand the here and now (t = 0), and these conditions will remain crucial for possible futures, if viewed as frozen or fixed in time (t = n).

The *conditions* identified here as representing realities in the here and now (Fig. 9.3b) relate to the real and the relative, and combinations of the two which we refer to as relationalism (underlining our differentiated world view as a 'matter of degrees of static complexity'). The idea that the various conditions expressed in Fig. 9.3b (for example, causality as something between 'direct' and 'remote') remain unchanged in the transformation process from the here and now to a future and an idealist perspective on the world is an assumption we call linear reasoning. Here we challenge this *linearity*.

There are various arguments positing that the world hardly ever evolves linearly or exponentially. The world's evolution may occasionally appear to follow a linear path: viewed from a distance it becomes clear that a 'linear' path is often no more than a stable stretch between general instability. Change is ever present and all too often behaves discontinuously. Cities, for example, grow and decline while undergoing various phases of transition. Economies lurch from one bubble to the next, and the stock market barely ever maintains a trend. Institutions come and go, and often do not match up to the tasks they are intended for. Municipal boundaries are often a nineteenth-century construct conforming to even older power relationships, and while the municipality's responsibilities emerge from twentieth-century legislative powers, it is confronted by the problems and challenges of the twenty-first century. The world is often fragmented, out of balance and in processes of discontinuous change: in short, it is *non-linear*.

Non-linear states are addressed by the complexity sciences, making these complementary to spatial planning and its *differentiated world view*. We have seen that spatial planning and its differentiated world view comes with *conditions*: conditions which are contingent and post-contingent between a certain and an uncertain world view, and which are a consequence of and a mix of the technical and communicative rationales. Both the technical and the communicative rationales lack a time reference (De Roo 2010; Hillier 2007). In a linear world, there is no need for a time reference. Both the technical and the communicative rationales closely focus on 'per se' decision-making processes. These decision-making processes are considered as taking place in the here and now. Consequently the world is either predictable from a technical rationale perspective, or there is consensus about how to act from a communicative rationale perspective. The result is a kind of planning that narrows down planning issues to one particular moment: at t = 0. In that sense, planning is considered a-temporal (Hillier 2007). A-temporal planning: a contradiction in terms. Nevertheless, this is what contemporary planning is about.

This a-temporal attitude in planning has been subject to critique. Rittel (1972) Webber and Christ-Churchman introduced the idea of 'wicked problems': those which are fundamentally impossible to grasp in their entirety. Doxiades (1968) and his Ekistics movement introduced an alternative view of reality as multilevel, interconnected and evolving. Alexander opposed the idea of a world controlled by planners and politicians desiring to design, develop and allocate spatially fixed and stand-alone groups of functions in his famous paper 'a city is not a tree' (1965). He considers tree-structured space as having no overlaps, and therefore lacking identity and character. Instead, he elaborates on semi-lattice structures and connections representing more 'natural,' robust links between functions and space, likely to result in appreciated urban fabric. The 'wicked problems,' the 'world in flow' and semi-lattice structures cannot be dealt with by believing only in the existence of discrete problems with a beginning and an end which are there to be solved definitely, or in problems which are agreed upon by consensus, not solved explicitly but structuring processes in such a way that these are understood by the actors involved. Scholars such as Batty (2005) and Portugali (2000, 2011) have demonstrated the possibility of the world being non-linear and the potential impact this perspective has on planning. Others have considered how planning, landscaping and architecture would look if the disciplinary debates digested these non-linear ideas (Barnett 2013; Boelens and De Roo 2014; De Roo and Rauws 2012; Hillier 2007; Marshall 2009; Portugali 2000; Schönwandt et al. 2012; Weinstock 2013).

If we consider a non-linear world as more realistic than a linear one, the planning discipline has not yet devised a rationale that frames situations as 'becoming' (see Fig. 9.7). This would require a 'non-linear kind of rationale' (De Roo 2010) for spatial planning. Consequently, we have to reconsider the bridge we have constructed between a real, relative and relational view, and an idealist view of the world. While idealism is about our ability to deconstruct reality as we know it and to reconstruct it in such a way that it enables us to imagine a possible reality, we do not yet have a rationale that can explain how the constraining and enabling conditions (Fig. 9.3b) will respond to transformations of the way towards a possible future. We are left with guesswork, hope and embracing the linear.

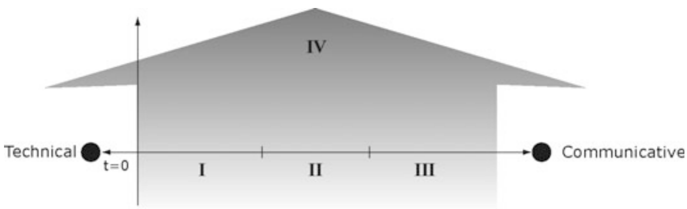

Fig. 9.7 The holy spectrum of planning viewed from a temporal perspective (De Roo 2012)

9.8 Framing the Non-linear

The complexity sciences offer some guidelines for considering a route towards an unfolding future, although these do not yet come with a *holy spectrum*, a contingency, a post-contingency or a consistent world view we could consider 'differentiated.' The complexity sciences do come, however, with various fragmented conceptions of an evolving and emerging reality. These conceptions do, to some extent, offer us a frame through which to consider a route towards the future.

Situatedness is the first of these. In a non-linear environment we do not observe isolated objects, entities or events. Nor do we observe actors reaching consensus about a particular issue in the sense of taking a firm decision. We have to accept that situations as we encounter them (in non-linear environments) are fuzzy, fluid and vague in their relationships with their surroundings. Situations emerge from various directions and trajectories, having evolved from individual pasts to a point where their paths merge in the sense that we see them represented by a manifestation in the material world we would label a single 'situation.' This merging relates strongly to the idea of 'assemblages' mentioned above (Hillier 2007; Van Wezemael 2008). The merging of paths and trajectories is often unintentional and conditioned by the contextual environment. Such an environment is never a plain level field. Instead, it will be unstable and discontinuously transforming, affecting the various paths and trajectories which evolve within it and with it. Some would consider this as a path-dependent route in a 'fitness' landscape (Barnett 2013). This 'situation' is likely a construct relating to various levels of scale, perhaps particularly manifest at the meso-level (with the whole being manifest), though also strongly related to the micro-level (in system theory: the parts that make a whole) and macro-level (the context). The 'situation', when looked at closely, is then a multi-level perspective (Hartman et al. 2011).

If we become aware of a 'situation,' it is likely to be sufficiently manifest to be recognized by others, to become a topic for discussion and, perhaps, trigger collective action. Such a situation is continuously in a state of becoming. A neighbourhood in decline is a good example: it is the result of a slowly progressing state of becoming. However, when is a neighbourhood no longer in an acceptable state? When is renovation desired? A neighbourhood in decline is likely to be a persistent problem. However, a situation may well disappear or resolve itself over time, as the paths and trajectories that make it up continue into the future, independently or in interdependency with other paths and trajectories. As a result, time can be enough to dispel a situation; time can continuously transform how matters stand in comparison to when we first considered the situation an 'issue'. A traffic jam is the obvious example of such a situation, appearing and disappearing as traffic moves forward. We tend to intervene when such situations become persistent and are accompanied by negative consequences, as might be the case in a pile-up.

All in all, situatedness relates to interdependent trajectories, path dependency, contextual multi-level states of becoming and being manifest to the observer. Situatedness relates therefore to realism, relativism and relationalism. By stressing the aspect of becoming, idealism also enters the picture. Situatedness is about being place and time-related: a manifestation within a place-time continuum. Every tick of the clock moves us forward in time, a process characterized by spatial movements which trigger processes of continuous acknowledgement and reformulation of our ideas about reality, and consequently a continuous reinterpretation of facts. Having acknowledged time as relevant, planning then requires rationales which either extend the real into the future or bridge the real and the imaginary.

Emergence, the second notion offered by complexity theory, occurs between order and chaos (Barnett 2013; Weinstock 2013). This expectation is the trademark of the complexity sciences. It is the consequence of the contextual environment being unstable. A fully ordered environment is an environment resistant to change —what some would call 'dead' (Lister 2008)—and therefore not open to development and progress. A persistently chaotic environment might lead to destruction, clashes and collapses, pushing us out of the arena of development entirely. Between order and chaos we can identify potential for development to occur. Development therefore relates to instability, which in turn allows room for creativity. Instability creates 'potentiality differences' (a state of being out of equilibrium), symmetry breaks (Bak 1999) which could lead to criticality, mismatches between structures and functions, and a mismatch between what is and what plausibly could become. Emergence stresses that environments are always ready for change, if not already in a process of change (or of 'becoming'). It is not a change from A to B, but a change which gradually adds or subtracts energy, causing situations to join, move alongside, merge with and adapt to the changes and the turbulent fields which are part of the contextual environment. The result is likely to be a transformation of the situation within a transforming environment, set in motion by an attempt to reach a better state of becoming. The contextual environment conditions the state of being 'in between order and chaos' and is therefore conditional to emergence.

Transitions are the third frame through which we will view complexity theory's offering to planning practice. The moment we add time to the concept of the *holy spectrum* (which we have previously defined as a-temporal as a-temporal), we accept a world in flow. A situation earlier considered as being 'simple and straightforward' now has to be considered as 'relatively stable.' A situation earlier seen as 'very complex' we would now call 'emergent': a shift from open systems to emerging networks. Relatively stable situations will never be entirely fixed or ordered, and emerging networks are unlikely to become completely chaotic. If they were, this would mark the end of both situations. Instead, we will see that all situations are open to transition (De Roo 2010; Rotmans et al. 2012). In a relatively stable environment this might occur every now and then, perhaps barely noticeably but nevertheless happening. In emerging environments, a continuous process of transformation makes it difficult to clearly identify one transition among many—with a defined beginning and an end—in between two stable periods. However, that is precisely what a transition is: a dynamic period where a system co-evolves from

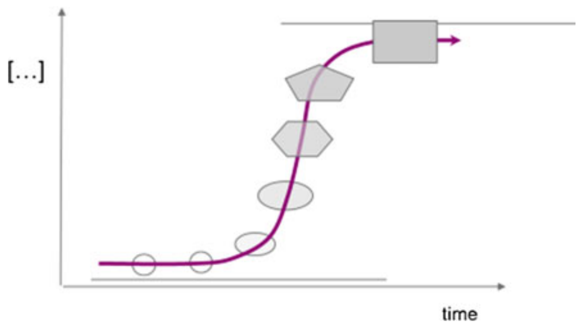

Fig. 9.8 Transition and co-evolving structure (*circle* to *square*) and function (*white* to *grey*)

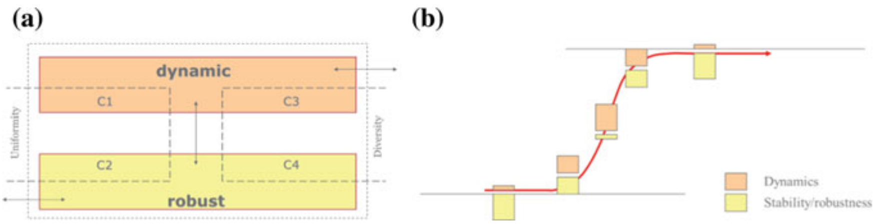

Fig. 9.9 A complex adaptive system (**a**) in a process of transition (**b**) (Source: De Roo 2012)

one stable period or level to another, seeking a better fit with its environment. Moreover, while the system is in transformation, it will undergo a process of change or becoming in which structure and function co-evolve (see Fig. 9.8).

Complex adaptive systems are the fourth frame offered by complexity theory. We have seen how *the holy spectrum of spatial planning* relates to various system classes: Class I representing closed systems, Class II representing feedback and circular systems and Class III representing open network systems (Kauffman 1995; Langton 1992). A fourth class of systems, called 'complex adaptive systems' (Waldrop 1992; Wolfram 2002), are not just a bunch of nodes interacting in a closed, inwardly oriented structure or in an open and externally oriented network. Instead of one node representing a system or a part of the system, a complex adaptive system consists of two internally interrelated layers of robustness and dynamics which jointly interact with their environment between order (a uniform state) and chaos (diversity), continuously looking for the right *conditions* to evolve, trying to find a best fit with the environment and to develop and progress while transforming into another representation, entity, or situation (Fig. 9.9).

Finally, *self-organization* is the internal restructuring of a system open to and being affected by its environment. Through a process of internal restructuring, the system produces new pattern formations. These are steps in the system's transformation towards a new identity. Prigogine (Nicolis and Prigogine 1977) identified these systems as being *dissipative*: the ability to cause the interdependency with external influences to resonate internally. These influences create both a symmetry break and criticality (Bak 1999). The moment criticality is achieved, energy is released, causing parts of the system to act in order to adjust their behavior to the symmetry break. The moment criticality is achieved and action is triggered, a non-linear process follows: the result can be minimal or great, and the scale of the impact is impossible to foretell. However, the non-linear process will spontaneously produce the formation of a pattern, which can be spatial, socio-spatial and social.

9.9 Patterns, Contingency and the *Holy Spectrum* of Planning

Pattern formation as a response to external influences is explained by Haken's synergetics as 'the working together of many parts, individuals, subsystems, groups' (in Portugali 2011: 60). Instead of the parts collapsing into inert and random structures (increasing entropy), we can see (in a nonlinear context) patterns emerging from interacting parts. These patterns represent a new order. The parts seem to conform to a common product: a pattern. This conformation is what Haken calls the *order parameter*, which 'enslaves the others to act in the same way and is called the slaving principle' (Portugali 2011, 62). Haken's *order parameter* relates to what is called the *power law* in mathematics, statistics and modelling, *attractor* in the complexity sciences, *convention* in the social sciences and *contingency* in the organizational sciences.

We have seen the *holy spectrum* of spatial planning representing a contingent and post-contingent relationship between a technical and a communicative rationale. The *holy spectrum* represents the planner's ideal decision-making line, which relates situations, issues, approaches and actions to their likely consequences, whatever the static 'complexity' of these situations. The *holy spectrum* connects the 'what' (target, goal or objective: the material world) with the 'who' (from command-and-control government to shared governance: the institutional world), producing the 'how' (from a technical to a communicative rationale, De Roo 2003). The *holy spectrum* represents the match or fit between structure and function, between institutional design and spatial design, between an object-oriented perspective and intersubjective interaction, between entity and value, between fact and story.

Could the story of this chapter end with a suggestion to consider the planner's *holy spectrum* as an order parameter, a power law, an attractor or the contingency which results in pattern formations? Why not? The interdependence between technical and communicative rationales produces frames of reference for planners that express the least effort state, a 'best fit' for each case. This 'best fit' or the ideal is not the real but a construct of what it could become. The real resonates in the ideal, and the real is responsive to the idea—to our ideas—regarding the real. This relates strongly to the duality in spatial planning and the interdependency between object orientation and intersubjectivity. In that respect, Haken's *order parameter* is also a construct, despite his focus on the material world. The *order parameter* is as much a mental construct as the *holy spectrum*: Both are a frame of reference which can be explored further to yield better ideas about how to relate spatial design and institutional design, not just for situations which 'are' but also for those which are 'becoming'. We could discover new 'order parameters' and new contingencies, for example contingencies which include time. These could reveal conventions which relate to non-linear, co-evolving and transforming processes.

Non-linear transformative processes would be greatly welcomed in spatial planning, being a discipline which must transform from an a-temporal focus into a temporal and non-linear perspective. In this chapter, we have made a serious effort to enhance the planner's vision, bridging contemporary planning ideas and the challenges posed by a non-linear understanding of entities, events and situations. It must be stressed that this effort is far more fundamental than merely a response to a Western world confronting a severe spatial and monetary crisis: it is a non-linear response to too much faith in linear growth and the certainties coming from a Newtonian kind of reasoning.

The challenge this chapter proposes (to the discipline, to the reader) is *to expand the differentiated view of planning* including the notions of time, change and non-linearity. Are we able to maintain well-defined differentiated views of planning under non-linear conditions? In our quest to find a clear answer to this challenge we will have to incorporate time within planning theory and practice. Does this mean that aside from realism, relativism and relationalism, serious attention must also be paid to idealism? Yes, of course this means planning has to seriously incorporate idealism as another frame of reference. Idealism refers to the capability of humans to imagine worlds yet 'to become'. Any kind of reasoning that addresses change and transition represents an idealist perspective. This raises the question of how to underpin change and transformation beyond the imaginative. Are we able to construct frames of reference based on non-linear rationales which allow us to relate institutional and spatial design to a world which is 'out of equilibrium'? Could we continue building on a differentiated world view and the 'what if, then …' routine while incorporating non-linear perspectives?

9.10 Conclusions

In this chapter we discussed realism, relativism, relationalism and idealism as essential cognitive features for understanding our environment. We consider cognition to be more than a mechanism for perceiving and responding to information reaching us through our senses. We implicitly centered our view on higher mental processes, which include reasoning, perceiving, imagining, creating, conceptualizing, symbolizing, memorizing and learning processes (Flavell 1985). In this chapter we emphasize perceiving experiences of an environment with all its qualities, ranging from clear objects to fuzzy social constructs (subject-object orientation), and sharing mentally produced values, meanings, concepts and ideas (intersubjective orientation). These four cognitive features together allow us to grasp the world, experience it, discuss it with others and develop a differentiated world view. *A differentiated world view* is considered key to spatial planning as it relates categories of planning issues (simple, complex, very complex and transforming, co-evolving and adaptive issues) to particular approaches and actions out of which consequences can be imagined. These cognitive features are also the legitimate foundations for analysis and synthesis, and in turn the base for the creativity and associative mental powers which allow us to consider plausible futures. These foundations bridge the world of rationale with the world of design; the cognitive features discussed in this chapter are important lenses through which to explore our reasoning about and our cognitive perceptions of a world which we consider non-linear. These perspectives will affect our thoughts about spatial environments and the daily living conditions they harbor, how we evaluate these and our aspirations to intervene—when and where necessary—by designing a well-defined future or guiding non-linear, spontaneous spatial developments towards an undefined becoming.

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Chapter 10
Global Scale Predictions of Cities in Urban and in Cognitive Planning

Roni Sela

Abstract This chapter presents preliminary research findings regarding the relations between complexity theories of cities (CTC), professional urban planning and cognitive planning—a domain of cognitive science referring to planning as a cognitive ability. Contrasting former findings from each of these domains reveals contradictions between their conclusions about the roles of predictions and plans. On the one hand, limitations on usage and implementation of predictions in planning practice have elicited 'prediction free' urban planning solutions. On the other hand, such solutions may ignore the basic human tendency to continuously predict the future, and the future of cities is no exception. Observing these contradictions in the context of cities as complex, self-organizing systems, findings of the current research suggest that global scale city plans (i.e. plans for the whole city, like Master-plans) are not only a technical product of certain 'prediction based' governmental mechanisms. The chapter will draw from the broad context of cognitive perceptions of complexity and uncertainty as general phenomena, in relation to individuals' fulfilling or falsifying behaviors towards urban plans. Specifically, it will suggest the role of urban plans as anchoring or guiding predictions that would further generate individual's planning behaviors.

This chapter is part of a Ph.D. research on cognitive aspects of planning and their implications for urban planning, conducted at the Porter School of Environmental Studies, Tel-Aviv University, under the supervision of Prof. Juval Portugali from the department of Geography and the Human Environment, and Prof. Dan Zakay from the school of Psychological sciences. The research was supported by a grant from the Porter School of Environmental Studies, Tel-Aviv University.

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10.1 Prediction in Urban and Cognitive Planning

10.1.1 Prediction in Urban Planning

Complexity theories of cities (CTC) put forward the idea that how cities evolve is inherently unpredictable. This unpredictability is the result of non-linearity (no predictable cause and effect relationships), one of the basic features of cities as complex and dynamic systems (Portugali 1999). Non-linearity implies that city dynamics have an irreducible uncertainty about them; actions and plans in the city may generate impacts in various non-correlated and unpredictable ways, and at various city scales[1] (Christensen 1985; Portugali 1999; Bertolini 2010). Tannert et al. (2007) define this kind of uncertainty as *ontological*, i.e. characteristic of the entity itself, derived from its stochastic features, and thus not reducible or resolvable (as opposed to *epistemological uncertainty* which is due to lack of understanding and can be reduced with more knowledge). De Roo (2010) described several facets of complexity in urban planning that contain uncertainty: the city as an entity by itself, the growing complexity of planning practice and theories, and the sociological and political complexity of planning situations. Yet not all CTCs that deal with these different facets of planning complexity share the assumption of inherent unpredictability, and this distinction is reflected in urban planning practices. For example, a focus on the ways of reaching consensus on a desired urban plan, however inclusive this pinning down of a single agreed vision of the future may be, suggests an underlying notion of a reducible (epistemological) uncertainty (Bertolini 2010).

One practical meaning of understanding the uncertainty of cities as ontological is the idea that wide-ranging, long-term predictions and plans may not be useful at the global scale of the city because of its unpredictable course of development (Portugali 1999, 2004; Alfasi and Portugali 2007, 2009) a state that in the current study is termed ***scale specificity*** (Sela, Ph.D. dissertation, forthcoming). Alfasi et al. (2012) demonstrated this problem using a remote-sensing and GIS-based Plan Implementation Evaluation (PIE) analysis to study the impact of a statutory plan for Israel's central district on its actual development. Their findings indicate that regulatory land-use planning has a limited effectiveness when applied to complex, densely populated districts with fundamental gaps between the original land-use assignments of the district plan and the actual development.

Instead of global scale *prediction-based* urban plans, such as is found in statutory master-plans, Alfasi and Portugali (2007, 2009) proposed a *prediction-free* 'urban code' of planning guidelines based on the substantive qualitative (i.e. in relation to people's perceptions and norms) dynamic relationship between the various physical elements of the environment. These prediction-free guidelines represent a heuristic approach as a substitute for global scale plans. Portugali (2011) explained that while this kind of 'self-organized' prediction-free planning is relevant to the global scale of

[1]The general definitions of scales as used in the research are: *global scale*—the whole city, *mezzo scale*—a city neighborhood, and *local scale*—a house or city block.

the system, some planning acts carried out at the smaller, mezzo or local, scales of the city represent the 'classical planning' that applies to simple closed systems, such as prediction-based plans that must be fully controlled, like the planning of a bridge—i.e. the bridge structure should be fully planned and its physical performance predicted, but its influence on large-scale city dynamics cannot be. This distinction between classical prediction-based and self-organized prediction-free planning activities defines a core difference concerning the global-scale future vision of the city: It is a pre-requisite (with various degrees of flexibility) in most urban planning approaches, but is not a requirement for applying the urban code. This distinction resembles the difference between some planning heuristics (e.g. 'means-ends and planning method heuristics), in which a goal state is pre-defined and there are limited cognitive resources with which to handle information regarding how to proceed towards that goal (Newell et al. 1958), and decision-making heuristics (Tversky and Kahneman 1974), which allow decision by comparison to current information without the prerequisite of a defined goal state.

Although frequent, the limitations on the predictability and controllability of city dynamics are often not acknowledged. Alfasi et al. described how gradual deviation from the development plan was obscured when land uses not conforming with the existing plan were incorporated into a new plan, such that "instead of directing development of the built environment…the statutory land-use plan is marginalized by the case-by-case dynamics of actual construction" (2012: 875). Another source of these limitations' lack of acknowledgement may be that little research has been devoted to evaluating the success of plan implementation (Talen 1996; Couclelis 2005). A different explanation proposed by this current research connects to the cognition of city agents as cognitive planners (see next section) and to their perception of the uncertainty that they believe characterizes city dynamics. I suggest city agents tend to perceive the uncertainty of city dynamics as epistemological, and that these perceptions are being reflected in current urban planning practice. An epistemological view of uncertainty may also bound acknowledgement of the limits of predictability in urban planning, so that predictability is perceived as higher than implied by some CTC views.

Assuming that urban planning is to some extent a reflection of individual planning processes, what may be the meaning of 'scale specificity,' in which the efficiency of predictions is restricted to specific urban scales, for individual people in the city? Are the planning agents aware of these limitations? Do they think and plan in relation to the global city scale? A rough distinction may be made here between urban planners involved in formal planning procedures and the general public, regarding the level or type of planning both types of agents is engaged in. Professional planners are engaged in the planning *of* the city, as well as in creating the planning procedures, i.e. the planning of planning. This daily professional engagement with planning makes it likely that they think more often about the global scale of the city. The general public is mainly engaged in planning *in* the city (such as when going from place to place). The general public is also engaged in the planning of the city, but in a more local context and latent form (Alfasi and Portugali 2007), such as by planning a house and its surroundings or participating in public hearings about changes in the city. As presented in the next section, findings from the study of cognitive planning suggest that all these agents continuously generate predictions and mental simulations.

10.1.2 Cognitive Planning and Mental Simulation: The Human as Incessant Planner

Planning as a cognitive ability is a set of complex conceptual activities that anticipate and regulate behavior (Scholnick and Friedman 1987), and which have a self-organizing and reflective nature (Das et al. 1996). Different theories have defined cognitive planning in various ways and used the term to account for various facets of functioning. A source of this vagueness is that planning includes several structural components (representation, choosing a goal, deciding to plan, formulating of a plan, executing and monitoring, and evaluation), and occurs simultaneously on three levels: in the reality of a problem or situation, in accordance with an imagined scheme and in the mediation between the scheme and behavior (Scholnick and Friedman 1987).

Ward and Morris (2005) point to a dichotomy in the cognitive research of planning between *well-defined* and *ill-defined* domains. This dichotomy refers to the level of construction of the domain or problem in which planning occurs, in regard to the completeness of information: In a *well-defined* domain, the planner has all the necessary information regarding the start state, state of the goal and the 'rules of play' which determine the possible actions that can be taken to transform one state into another. In a well-defined domain, finding a solution can be likened to searching the abstract state space for a pathway that connects the start state to the goal state (Davies 2005). In an *ill-defined* domain, some of the necessary information is not fully specified. In particular, a concrete and visualizable goal state is missing (Ormerod 2005). Burgess et al. (2005) suggest that the ability to deal with this "ill-structuredness" is the greatest determinant of performance in everyday planning situations. In spite of that, much of the cognitive and neuro-cognitive study of planning over the years focused on decision-making in well-defined scenarios and domains (Scholnick and Friedman 1987; Ward and Morris 2005; Ormerod 2005; Grafman et al. 2005).

One major element that different definitions of planning have in common is mental simulation of future actions and their outcomes (Mumford et al. 2001). In Kreitler and Kreitler's words: "Planning is based on dealing with the hypothetical, with what is not yet present physically" (1987: 205). Gilbert and Wilson (2007) described mental simulations as the internal representations of the external world the brain combines from incoming and stored information, in order to prospect, ("pre-experience") or predict future consequences. Mental simulations were also defined by Buckner and Carroll (2007) as imagined alternatives (for example, perspective changes) constructed based on past experiences while thinking about the future. The ability to simulate the future is based on the frontal and medial temporal lobes, which are also associated with planning and episodic memory (Buckner and Carroll 2007). Episodic memory, possibly the key cognitive function for prediction in planning (Tulving 1983) offers one the ability of 'Mental Time Travel' between one's subjective times of past, present and future: to travel back and forth in time between events and experiences that have already been encountered, and planned or imagined future events (Tulving 2002).

This research studied simulation and prediction in the complex and dynamic (i.e. ill-structured) domain of the city. To clarify the distinction and connection between the terms, *prediction*, as defined by the Oxford advanced learner's dictionary, is saying in advance that something will happen (a similar meaning to *forecast*, which is prediction on the basis of information). *Simulation* describes the representation of a real situation in another form. While simulation by itself has no future (or any other time) orientation, it is the only way to represent future situations, so that predictions include some form of mental simulation. Note that neither term references accuracy. The issue of accuracy, as it pertains to this work, will be addressed later in this section.

In his discussion about the cognitive development of future thinking, Haith (1997) described four categories of thinking about the future, defined on the basis of their relationship to memory. These categories are briefly presented here with reference to their expression in urban and spatial planning.

(a) *The future as continuation of a repeating past:* the expectation that what has happened before will happen again, based on the constant repetition of events. This simple form uses regularities of phenomena to prepare for that specific phenomena to recur, and was demonstrated as early as 6 weeks old, with babies looking for the re-appearance of a picture. The cycle of seasons, day and night, and the order in which traffic lights change are all examples of this category that influence planning in the environment.

(b) *The future as projection of past trends:* the formation of expectations for the future based on extrapolations of current trends (rather than on repetition of the same events). A model of the future is created based on the past and present although the future state may have no precedent. This is done on the basis of memory and the current context, which are generalized to model new situations. From a developmental perspective, such generalization of experience depends on the ability for categorization that exists at some level in infancy and improves considerably throughout the early years.

Scientific models such as urban simulation models represent this (and to a lesser extent the next) type of future thinking. An early example is the Malthusian model from the close of the 18th century, which extrapolates a catastrophe for humanity due to a geometric (exponential) increase in the global population but an arithmetic (linear) increase in food supply.

(c) *The future as construction from analogy:* While the projection of past trends is related at the individual level to an extrapolation of one's own experience, constructing the future from analogy is based on induction from the experiences of others. Cognitively, such thinking emerges in infancy (displayed in the ability to imitate) and is largely developed through social interaction in childhood, when children form a knowledge base from others and can use this knowledge base to form future models.

Predictions based on analogies have recently been (and still are) used in geo-political strategies concerning social, military and economic trends. An example of analogy on a regional scale is the series of revolutionary waves of the 'Arab spring.' Another example is that analogies from the extinction of some species are the basis for efforts to preserve existing flora and fauna.

An un-desired projection or construction from analogy of the future (as was the future state predicted by Malthus, or the threat to the survival of the Giant Panda) may, as illustrated by Portugali (2008) for the urban context, evoke opposing behaviors in order to prevent this future from materializing, thus causing a 'prediction paradox' in which the prediction itself is also the cause of its falsification. In Chap. 11 of this book Thagard describes the computational formulation of emotional coherence between elements with positive or negative emotional valence that may explain such 'paradoxical' decision making in urban dynamics.

Another aspect, relevant to the two former categories as expressed in computerized land-use models is Couclelis' (2005) criticism of the detachment of the models from the genuine future thinking that is required for spatial planning; the models (erroneously) assume that the outside world remains pretty much the same over the planning period, and does not hold any major surprises that may affect the system's boundary conditions. Wachs (2001) noted that forecasts based on such models may not be regarded as a vision of the future, but rather as a foreseeable consequence of the intersection between causal variables presumed to follow their historical trends. Even though current Cellular Automata (CA) and Agent Based Models (ABM) simulate dynamics in complex and open systems (Heppenstall et al. 2012), the claim is that core subjective assumptions held by the modeler play a larger role in determining the forecast than does the complexity or sophistication of the specific model employed (Wachs 2001).

(d) *The future as imagination and invention:* According to Haith (1997), this category refers to a future model that is originally imagined, invented or created without any precedent source, such as children's games that rely on make-believe. Proponents of planning as a visionary, future-oriented process (e.g. Isserman 1985; Myers and Kitsuse 2000; Myers 2001; Couclelis 2005) suggest using techniques such as scenario writing, visioning and storytelling to balance the constraining "backward looking" (Couclelis 2005: 1359) nature of models. However appealing, this cognitive category of future thinking may be controversial because of the arguable notion of no precedence (explained for example in Portugali's (2004) discussion about changes in the city form, which are based on self continuity—the reproduction of structure and form of existing objects in new artefacts). Using Haith's examples, a pretend game of a trip to the moon includes the primary features of any journey, and the airplane was developed based on analogies from birds. Porat (2006) demonstrated this in the finding that science-fiction representations of future cities are based on mechanisms of exaggeration and symbolization of the known, already experienced, reality. This strong reliance of 'genuine' future thinking on stored knowledge is referred to as constructive episodic memory by Schacter and Addis (2007), and was well described by Gilbert and Wilson in the statement that: "Mental simulation is the means by which the brain discovers what it already knows" (2007: 1354).

Haith (1997) notes that these four categories do not constitute a straightforward developmental sequence, as each form of thinking may be expressed at various times, from early childhood to adulthood. As mentioned above, spatial modeling of the future uses all four, but mainly the two intermediate categories. This categorization is relevant to the current discussion because, according to Haith (1997), the limitations on the ability to think about the future place an upper limit on the ability to plan. Furthermore, applying a certain kind of future thinking would define the limits of the (urban) prediction by means of its flexibility and accuracy.

While Scholnick and Friedman (1987) regarded cognitive planning as a voluntary, self-conscious and intended behavior, more recent findings from neuro-cognitive studies (e.g. Spreng et al. 2009; Buckner et al. 2008; Gilbert and Wilson 2007; Buckner and Carroll 2007; Bar 2007; Addis et al. 2007; Hassabis and Maguire 2007) suggest an involuntary and continuous occupation in future thinking, i.e. in the future simulation part of planning. These studies have connected the mental ability to simulate the future to a 'core network' that is responsible for other abilities representing scene construction (Hassabis and Maguire 2007) or self-projection—the ability to shift perspective to an imagined future event while referencing this event to oneself (Buckner and Carroll 2007). The core network is also associated with a 'default mode' (Raichle et al. 2001) that is active when people are not engaged in directed behaviors or focused on the external environment. This connection may imply that 'what people tend to do when not busy perceiving the present is to simulate the future' (Buckner et al. 2008; Buckner and Carroll 2007; Gilbert and Wilson 2007). Indeed, Berntsen and Jacobson (2008) and Finnbogadottir and Berntsen (2013) reported that involuntary Mental Time Travel (as described by Tulving 2002) is common in everyday life, and have found that involuntary future projections were as frequent as involuntary memories (but more positive). Bar (2007) illustrates this constant tendency to generate predictions through accessing information in memory, by the difficulty people who study meditation have concentrating on the 'here and now,' often finding themselves unable to put thoughts of the future or past out of their minds.

Simulations of the future are rarely a complete and reliable predictor of future events and experiences. Gilbert and Wilson (2007) defined four kinds of errors in human simulations of the hedonic reactions to an un-experienced future, stating that "mental simulation is ingenious but imperfect". According to Gilbert and Wilson (2007), in comparison with perceptions (the mental representations of a present event), simulations of future events are usually unrepresentative, essentialized, abbreviated and decontextualized. It should be noted, however, that findings from the cognitive and neurocognitive study of planning demonstrate that people may not be very accurate planners, not only because of their limited ability of anticipation while thinking about the future. Kahneman and Tversky (1982) have used the term 'planning fallacy' to describe the underestimation of time required to complete a project, a fallacy that is attributed to the tendency to base predictions on singular (case specific) information and neglect distributional information (the knowledge about base-rate data according to distribution of outcomes in similar cases). More difficulties arise from other forms of bounded problem solving and decision-making (e.g. Davies 2005; Ormerod 2005), bounded memory (e.g. Gilhooly 2005; Owen 2005; Meacham and Leiman 1982), and the problem of generating a shared representation (shared mental model) when planning in groups (Portugali and Alfasi 2008; MacEachren and Brewer 2004; Zhang and Norman 1994). As described in the former section, the problem of predicting a city's future arises also from the characteristics of the city as a complex and ill-defined domain. Despite, or maybe due to, the limitations in producing complete and reliable simulations and predictions, Buckner and Carroll (2007) suggested that the real adaptive function of 'future oriented' brain mechanisms like episodic memory and the 'default network' is not in their accuracy in creating specific and exact representations, but rather in their ability to flexibly envision the future: to simulate multiple alternatives of what would happen next.

10.1.3 Integration—An Apparent Contradiction

Characteristics of both the human planner and the city inherently limit the efficiency of urban plans and the possibility of implementing them (in full) in practice. These limitations are one of the causes of a 'crisis' in planning practice (De Roo 2010), and imply the possibility that above a certain scale planning is not useful (Alfasi and Portugali 2007, 2009), suggesting that urban plans have 'scale specificity'. However, acknowledging the uncertainty of cities as ontological and that, as a result, predictions about its large-scale and long range future are impossible and thus undesirable may be contradictory to findings about the tendency of individuals (city agents) to continuously predict and simulate the future. Both cognitive research findings and urban planning practice show that, in spite of the limitations and inefficiency, planning and prediction are carried out constantly by individuals acting as 'cognitive planners,' as well as in the practice and procedures of urban planning exercised by professional planners. A practical example that illustrates this tension is that, in the creation of predictions about the city as a whole (an unpredictable scale if ontological uncertainty of the city is assumed), prediction is often necessary as a basis for the shared representations used by urban-planning teams. Deriving from these apparently contradictory observations, the research described in this chapter addresses whether an equivalent 'scale specificity' of individual predictions about the city exists. Is this human tendency limited or specific to a certain city scale? More specifically, what is the nature and role of predictions made by individuals about the city, in regard to different urban scales?

10.2 The Study Framework

In order to get more insight about the nature and role of predictions about the city and better tackle the question of scale specificity in individual predictions, the study examined three main aspects: the scale individual predictions applied to; general future orientation; and the accordance of self-perceptions of ability to predict and to influence the future with propositions of complexity theory of cities. The study also compares these aspects for different groups of urban agents: planners compared with non-planners, environmentalists with non-environmentalists, males with females and so on for other demographic groups.

Phase A of the research was an exploratory study in which 38 planners and 46 non-planners living in cities in Israel filled a semi-structured paper questionnaire about predictions and future aspects of their living environment. Participants were asked to draw a future picture of "the place they live in" as it they imagine it will be in 10 years, and to answer questions about the future of that place. By not defining what exactly we meant by place of living (house, neighborhood, city or country), it was possible to learn from the pictures to what scale participants referred when generating their predictions. Questions about participants' knowledge of formal plans and its relation to individual future pictures allowed us to draw a connection between aspects of cognitive and urban planning.

In *phase B* of the research, 348 participants from 34 cities in Israel answered a computerized adaptive questionnaire that focused on two forms of possible hierarchy of predictions. The first section looked at the hierarchy of scales of considerations in decisions about the place of living. In this part participants ranked the importance of scale and of specific information items for a real decision they made in the past five years about moving to another house. The second section looked at hierarchy in the role of predictions and formal plans involved in the assessment of future changes in the city. In this part participants were randomly assigned to one of three scenarios with high, medium or low certainty regarding the realization of a construction plan near their house, then answered questions about the predicted level and direction of changes in the area based on the current state and the scenario.

Phase C was a focused validation study that challenged the assumption generated on the basis of phases A and B that considerations that belong to the global scale (the city as a whole) would get the highest value of importance. In this study, 122 participants from 24 cities in Israel answered a computerized adaptive questionnaire in which they assigned a cost to information items that concern buying an apartment and belong to different city scales. The results did not validate the hypothesis that the global scale would have the highest importance, but did support the general conclusion that no scale specificity applies to individual predictions about the city.

10.3 Main Findings

The study can be summarized through three main findings. First, no scale specificity was found in individual predictions about the city. Second, formal urban plans may cognitively act as guiding predictions more than as concrete plans. Third, CTC implications about the limits of certainty and predictability are difficult to acknowledge. While the first finding answers the main research question, it was not addressed in this form before. The other two findings provide empirical support to existing ideas in CTC discussions, and are presented in detail in the following sections.

10.3.1 No Scale Specificity Was Found in Individual Predictions About the City

Individuals predicted across all city scales: In prediction without a specific task (such as drawing a future picture of their living place) the mezzo (neighborhood)

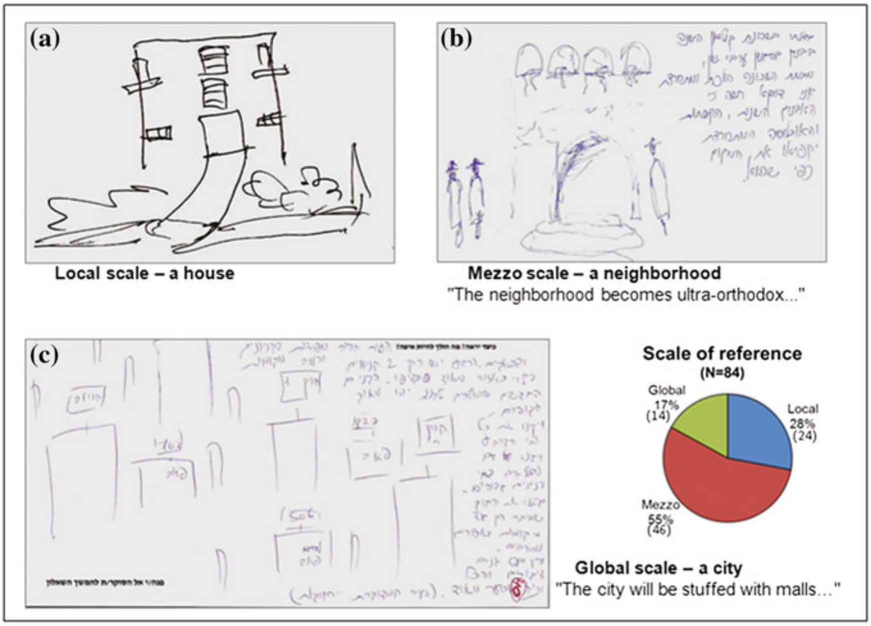

Fig. 10.1 Future pictures in each scale

scale was dominant, with more than half of the participants' drawings at that scale. However, both local and global scales were also predicted (Fig. 10.1). No connection was found between the scale predictions were made at and participants' knowledge about formal plans.

Information about the global scale of the city was required when deciding where to live: In evaluations of the importance of considerations for choosing a house or apartment, considerations belonging to all scales and to various aspects of life were found to be important to participants. No clear hierarchy of scales was found, meaning that global scale considerations were no less (and sometimes more) valued than those on lower scales.

10.3.2 Formal Urban Plans May Cognitively Act as Guiding Predictions More Than as Concrete Plans

Informal predictions produced similar effects to formal plans: this was demonstrated by an almost total insensitivity to the level of uncertainty that was presented in different scenarios about a construction plan: a rumor about a plan (high uncertainty), a plan that was submitted for approval (medium uncertainty) and a plan that is already being implemented (low uncertainty). As in the urban dynamic phenomena described by Portugali (2008), in the scenarios experiment participants assessed the future influences of scenarios with different uncertainty levels to be very similar. Results from randomizing scenario presentation (before or after responding to questions about the current state) demonstrated the subtle effects of predictions when 'entering the game', in that the awareness to the possibility of change due to the presented scenarios created higher perceived stability of the current state.

Formal plans were perceived more as predictions and less as concrete urban plans: Chances of realization attributed to rumors were higher than expected, and chances of realization attributed to a plan that is already being implemented were lower than expected. This may imply that city agents are acquainted with the dynamics (reversibility and changeability) of urban plans, even after their approval and 'launch'. It was also found that individuals still base their decisions on the information presumed to be provided by such plans, suggesting that, like mental simulations (Buckner and Carroll 2007), the importance of global scale plans is more in their use as *a general reference for behavior* and less as a fixed guiding tool, despite this being their original purpose in planning practice.

Regarding these two observations, it was found that owners of the place they lived in tended to be more sensitive to future changes in their environment, both in seeking relevant information and in the magnitude of reaction to it. Accordingly, a distinction on the basis of real-estate ownership may be relevant for classifying agents operating in the city's dynamics.

10.3.3 CTC Implications About the Limits of Certainty and Predictability Are Difficult to Acknowledge

The complexity of cities as discussed in theoretical formulations may not be perceived as intuitively when it comes to individuals' understandings of their roles in this complexity and its meaning for them. Complexity is usually referred to with a negative connotation (De Roo 2010), unattainable in full by mental operations due to the limited capacity of the mind (Alexander 1965) and the uncertainty that accompanies it as a feature one has to cope with (Christensen 1985). The question of scale specificity in prediction about different city scales at the individual cognitive planner level is, therefore, also a question of a planner's ability to acknowledge the uncertainty of the city. The distinction between a reducible-epistemological uncertainty and an irreducible-ontological uncertainty (Christensen 1985; Tannert et al. 2007) may be useful here: Assuming an ontological uncertainty ultimately means an inability to predict the long-range future of the city. However:

Individuals sought 'unpredictable' global scale information: High value was given to global scale considerations in creating a future picture and for decisions about the place of living. These considerations were social, cultural and economic in nature, aspects that according to CTC are dynamically involved in the city as an open system, thus unpredictable for the long range.

Perceived ability to predict the future of the city was higher than implied by CTC: In the scenarios experiment (see Sect. 10.3.2) more than 90 % of the

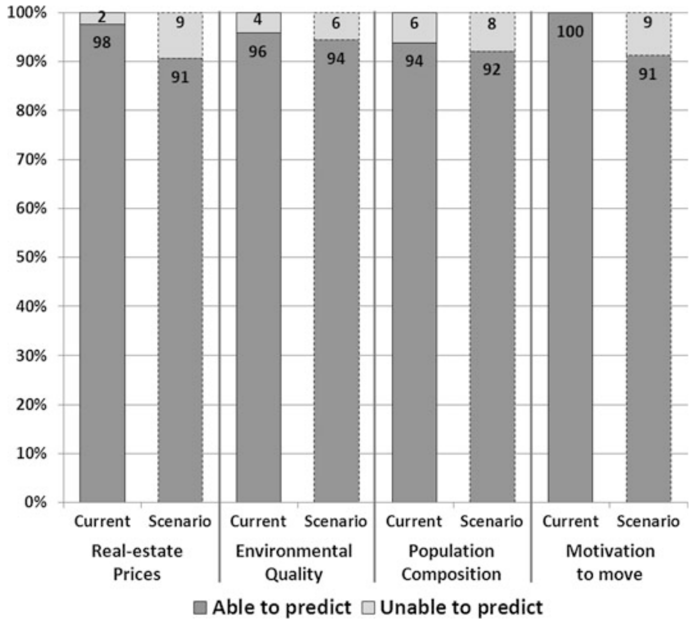

Fig. 10.2 % participants who felt able or unable to predict changes for 10 years from now on the basis of the current state and a hypothetical scenario

participants did not choose the option 'unable to predict' (changes in 10 years from now) when given the opportunity to do so (Fig. 10.2). It was interesting that planners and architects, who should be most aware of city dynamics, perceived their ability to predict changes in their city and neighborhood as higher than non-planners. These results may also be related to the bias of over-confidence in the precision of estimates described by Kahneman and Tversky (1982).

While not referring directly to cognitive planning, the same difficulty was described in relation to urban planning by Batty and Marshall (2012), who compared the overestimation of prediction ability in generating and enforcing wide range, long term urban plans to the difficulty to understand the true meaning of complexity in Darwin's Evolution theory for the *future* of species.

10.3.4 Related Findings

In addition to the main findings, two related findings were the relevance of the distinction between local, mezzo and global geographic scales, and dominance of global scale predictions in smaller settlements and of mezzo scale predictions in the larger settlements. This last suggests that the predicted scale was primarily based on geographical size: an area large enough to allow socio-spatial community interactions but small enough to comprise a conceptual and perceptual unit or category (Lee 1968; Lloyd et al. 1996; Gabora et al. 2008).

10.4 Concluding Remarks

In the practice of urban planning, cognitive representations of the future should be externalized and formalized. As in Haith's (1997) categorization of future thinking, the higher the category that is applied the outcome can be more flexible but may face more uncertainties about its realization due to deviations in the circumstances. Any formalization, however, departs from the ongoing cognitive-internal stream of simulation and prediction. CTC derived 'prediction free' planning solutions offer a high level of flexibility that corresponds to a state of irreducible uncertainty with no definition of 'visualizable ends' in the planning process.

Previous discussions about prediction-based or prediction-free planning have dealt with different faces of this question. In the discussion about the policy-making (used as a synonym for decision-making) aspects of planning, there were the idea of *Incrementalism*: the evaluation of development alternatives in '*successive limited comparisons*' (Lindblom 1959) and the idea of '*Mixed-Scanning*' where long term goals are required as *decision-guides* for both fundamental and incremental decisions (Etzioni 1967, 1986). From the face of social justice and collaborative planning, the question of prediction-based or prediction-free planning is not so much about the ability to create a correct vision but about the morality of doing so. Hatuka and

D'Hooghe (2007), and Davis and Hatuka (2011) described the utopian debate in urban planning, where utopian grand visions (like Howard's Garden City and Le Corbusier's Ville Radieuse) were given-up, accused of totalitarian coercion and physical determinism and of ignoring societies' multiple perspectives and future dynamics and uncertainties. These authors suggested that giving up 'the right to vision' has paralyzed urban planning and design, and that utopias should not be judged by success or failure in their implementation, but as a mediating tool, inspiring creative new ideas for the resolution of social conflict (Hatuka and D'Hooghe 2007; Davis and Hatuka 2011). Prediction-free cognitive planning is presented in some cognitive *decision making heuristics* (Tversky and Kahneman 1974) and the *hill-climbing planning heuristic* (Newell et al. 1958; Newell and Simon 1972). These allow the planning process to be bypassed by deciding upon comparison to current information without the need of a defined goal state. The cognitive debate mainly focused on the direction of prediction-based planning, whether it is a top-down hierarchical and sequential process (Sacerdoti 1977), or a multi-directional "opportunistic" process in which the planner responds to opportunities as they emerge, and thus may revise or abandon the original plan (Hayes-Roth and Hayes-Roth 1979).

The discussions presented in this chapter about predictions in urban planning concentrated on usefulness and appropriateness, and attributed the decision to predict or not to the certain governmental mechanisms and policies that are applied in planning practice. Cognitive and neuro-cognitive discussion concerns the way planning occurs: how it is related to predictions and their underlying brain mechanisms. Connecting the two domains suggests that generating predictions (of all scales) as part of cognitive planning is a basic human characteristic, and thus cannot be artificially excluded from the act of urban planning. Moreover, just like in cognitive planning, the role and importance of predictions in urban planning is suggested to be in making them, rather than their accuracy; predictions are anchor representations from which fulfilling or falsifying behaviors can proceed.

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Chapter 11
Emotional Cognition in Urban Planning and Design

Paul Thagard

Abstract This chapter discusses the relevance of emotion to urban planning and design, arguing for the following conclusions. Urban planning requires values, which are emotional mental/neural representations of things and situations. Decisions about how to design cities are based on emotional coherence. The concepts used in urban planning are best understood as a new kind of neural representation called semantic pointers. The social processes of planning cities and living in them can be modeled using multi-agent systems, where the agents are emotional. The cognitive, emotional, and social mechanisms underlying urban development are complex in that they are nonlinear, emergent, chaotic, synergistic, amplified by feedback loops, and result in tipping points.

11.1 Introduction

The design of cities requires cognition—mental processes that include planning, decision-making, problem-solving and learning. There is substantial experimental evidence that all of these processes have a large emotional component, where emotions are conscious experiences resulting from a combination of physiological changes and evaluations of the relevance of situations to goals (Thagard 2006; Thagard and Aubie 2008; Thagard and Schröder 2014).

How does emotional cognition contribute to urban planning? This chapter explores and defends the following claims in order to answer this question:

1. Urban planning requires values, which are emotional and mental—or neural—representations of things and situations.
2. Decisions about how to design cities are based on emotional coherence.
3. The concepts used in urban planning are best understood as a new kind of neural representation called semantic pointers.

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4. The social processes of planning cities and living in them can be modeled using multi-agent systems, where the agents are modeled as making decisions based on emotions.
5. The cognitive, emotional and social mechanisms underlying urban development are all complex: nonlinear, emergent, chaotic, synergistic, amplified by feedback loops and resulting in tipping points between conflicting practices.
6. The goal of making cities sources of creativity can be accomplished in part by understanding the social and cognitive processes that help people to be creative. Our understanding of these processes can be enhanced by computational models that provide social simulations of creativity.

11.2 Values in Urban Planning

Values are mental processes that are both cognitive and emotional; they combine cognitive representations such as concepts, goals and beliefs with emotional attitudes that have positive or negative valence. For example, the values associated with life and death require the separate mental concepts of *life* and *death* understood in relation to the connected emotional attitudes that view life as positive and death as negative.

Advances in neuroscience provide evidence that such mental states are neural processes that combine cognition and emotion. Concepts operate in the brain as patterns of firing in populations of neurons that are learned by sensory experience or formed by combining previous concepts. These patterns can work to classify objects and also make general inferences about them. Such neural representations are continuously bound with emotional activity carried out by populations of neurons in brain areas such as the amygdala, ventral striatum and ventromedial prefrontal cortex. From this perspective, values are neural processes resulting from binding cognitive representations of concepts, goals and beliefs together with emotional attitudes.

The emotional component of values might seem to suggest that values are purely subjective: just a reflection of individual whims. In philosophical ethics, the positions called emotivism and expressivism demote value judgments to statements of personal preferences (e.g. Ayer 1946; Gibbard 1990). Such philosophical positions, however, reflect a naïve view of emotions, which are not just perceptions of physiological states. Emotions combine such perceptions with cognitive appraisals that reflect an estimate of the extent to which your current situation promotes or threatens your goals, based in part on the emotional associations of words and concepts that are culturally acquired (Thagard and Schröder 2014). Such appraisals can be performed based on how the situation and its consequences affect goals, and on how well the goals considered fit with overall goals. Goals need not be arbitrary desires of a person, but can derive from fundamental human needs of everyone concerned: biological needs such as food, water, shelter and healthcare; as well as psychological needs for relatedness, competence and autonomy (Thagard 2010a).

Hence, even though values and value judgments are most plausibly viewed as neural processes, they can be objectively correct or incorrect based on the extent to which they fit with human needs. Such values are a legitimately and useful contribution to deliberation about how cities should operate and develop; when urban planners make decisions about housing, industry and transportation routes, they consciously or implicitly apply the values they hold concerning how that city ought to operate and how its inhabitants can benefit from living in it.

11.3 Cognitive-Affective Mapping

The role of values in urban planning can be illustrated using an innovative technique called cognitive-affective mapping, which supplements traditional kinds of concept mapping (e.g. Portugali 1996) by including positive and negative emotional values. A cognitive-affective map (CAM) is a visual representation of the emotional values of a group of interconnected concepts such as *city, automobile, and tall building*. This technique has already proved useful for numerous applications, from conflict analysis to literary interpretation (Thagard 2010b, 2011, 2012a, b, 2015a, b; Findlay and Thagard 2014; Homer-Dixon et al. 2013, 2014).

CAMs employ the following conventions:

1. Ovals represent emotionally positive (pleasurable) elements.
2. Hexagons represent emotionally negative (painful) elements.
3. Rectangles represent elements that are emotionally neutral or carry both positive and negative aspects.
4. The thickness of the lines in the shape represents the relative strength of the positive or negative value associated with it.
5. Solid lines represent the relations between elements that are mutually supportive.
6. Dashed lines represent the relations between elements that are incompatible with each other.
7. The thickness of the lines in the connection represents the strength of the positive or negative relation.

When color is available, CAMs conventionally represent positive—oval—elements in green, like the the urban traffic convention for “go”, negative—hexagonal—ones in red, like “stop”, and neutral rectangular ones in yellow, with no traffic analogy (see Fig. 11.1). The software program *Empathica*, available at http://cogsci.uwaterloo.ca/empathica.html, makes drawing CAMs efficient and fun. The name of this program reflects the aim of increasing mutual empathy between conflicting parties through depiction of the value maps of the people involved, for example concerning issues about light rail transportation presented below.

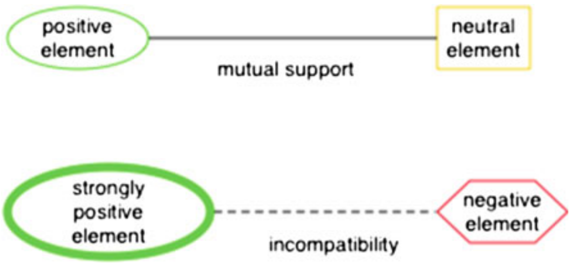

Fig. 11.1 Schema for a cognitive-affective map. Use of color is optional depending on the medium used

To illustrate the usefulness of CAMs in mapping values relevant to urban planning, I have used *Empathica* to produce value maps of the way two urban theorists—Le Corbusier and Jane Jacobs, often juxtaposed as representatives of opposing 'schools'—conceive the ideal workings of cities. Figure 11.2 maps the values adopted by Le Corbusier in his influential book *The Radiant City* (1967), first published in 1935. He encouraged the kinds of urban renewal that dominated much urban planning in the 1950s and 1960s, exemplified by the replacement of traditional housing with high-rise blocks with easy access to the new freeways that he imagined would order the growth of cities. Figure 11.3 shows the set of values defended by Jacobs (2011) in her scathing critique of modernist urban planning, first published in 1961. The two value maps serve to highlight the contrasting positive and negative values that drove modernist plans and the resulting New Urbanist backlash against them. They differ on numerous values, including that of planning itself, that is, whether planning is inherently desirable or destructive. The maps (Figs. 11.2 and

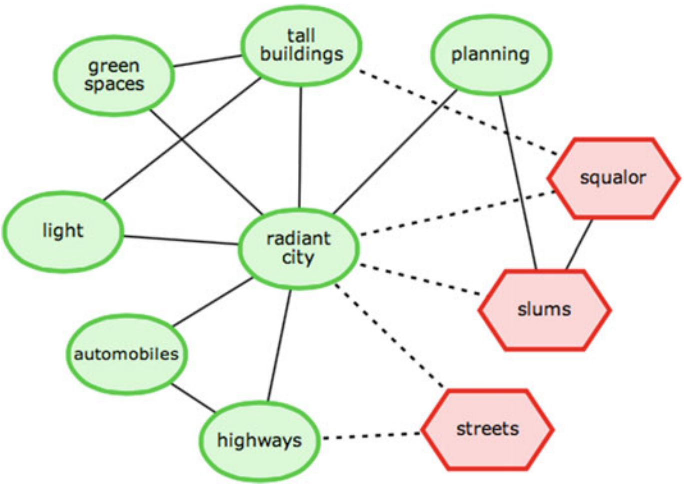

Fig. 11.2 Cognitive-affective map of modernist urban planning values, based on Le Corbusier. *Ovals* show emotionally positive concepts and *hexagons* negative ones. *Solid lines* indicate support; *dotted lines* indicate incompatibility

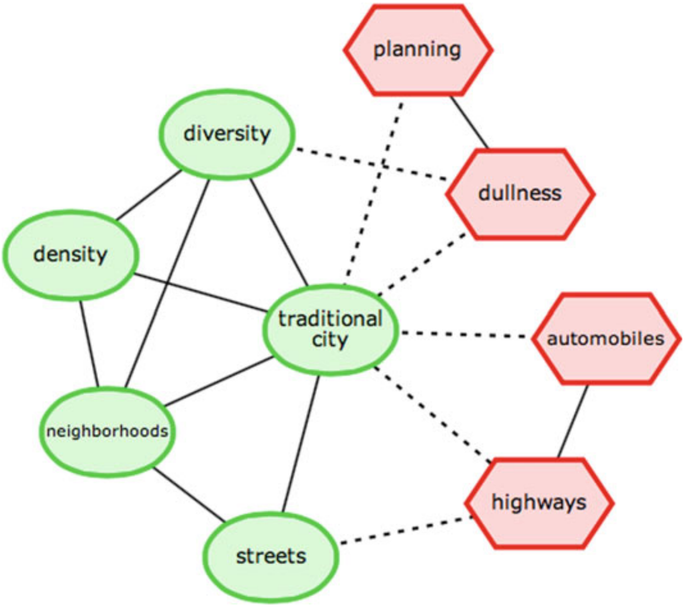

Fig. 11.3 Cognitive-affective map of new urbanist values of urban planning, based on Jacobs. Both maps were produced by the cognitive mapping program *Empathica*, available free at http://cogsci.uwaterloo.ca/empathica.html

11.3) show that values do not occur in isolation, but rather form connected systems that work together to influence decisions. The positive and negative connections are shown by the dotted lines.

At the second *Complexity Theories of Cities* conference held at the TU Delft in October 2013—and gathered in this book—I was told that there had been a plan in the 1960s to disrupt the lovely Dutch town by bringing major roads into the historical centre, in line with the modernist values shown in Fig. 11.2. Fortunately, the traditional values shown in Fig. 11.3 prevailed, and Delft retains its seventeenth-century organization and charm.

11.4 The Waterloo Region Controversy on Light Rail Transit

Cognitive-affective mapping can also be used to display the differences in emotional values in specific contemporary disputes, such as the controversy in my hometown concerning whether to implement light rail transit. Waterloo Region is a prosperous area in southwestern Ontario, about 100 km west of Toronto. The region has a population of 540,000, mostly concentrated in three contiguous cities: Waterloo, Kitchener and Cambridge. The regional government is moving rapidly forward with their plan to implement a light rail line from the north of Waterloo to the south of Kitchener, with a connecting rapid bus service to Cambridge. The dispute partly concerns unknown or contentious facts about the future of the network: such as how much the light rail project will actually cost, how many riders it will attract and whether the relation between these figures makes the project a responsible and sustainable investment. But the dispute also reflects some very different and highly emotional values held by both supporters and critics of the project. Cognitive-affective maps provide a concise and perspicuous way of displaying these value differences.

Figure 11.4 is a CAM of the values supporting light rail transit, derived from information on the website of the Region of Waterloo. Light rail is held to be desirable because it promotes goals such as moving people efficiently in order to avoid traffic congestion and building new roads. The light rail project is also intended to concentrate growth in established areas near light rail stations in order prevent urban sprawl into the countryside.

Opponents of the light rail project have a very different set of values, shown in Fig. 11.5. They emphasize the feeling that unpredictably high costs will lead to higher taxes and reduce regional prosperity. They would prefer to foster convenient car use through more roads rather than urbanization concentration and think that buses provide a cheaper and more flexible means of public transit than the project light rail system. But the residents of the city of Cambridge, to whom the project initially offers only such a bus system, are annoyed that they will contribute to the cost of light rail but will reap few benefits until it is eventually extended to Cambridge—at an unspecified time.

How can urban planning disputes such as the Waterloo light rail issue be resolved? Figures 11.4 and 11.5 make it clear that the issue goes beyond factual

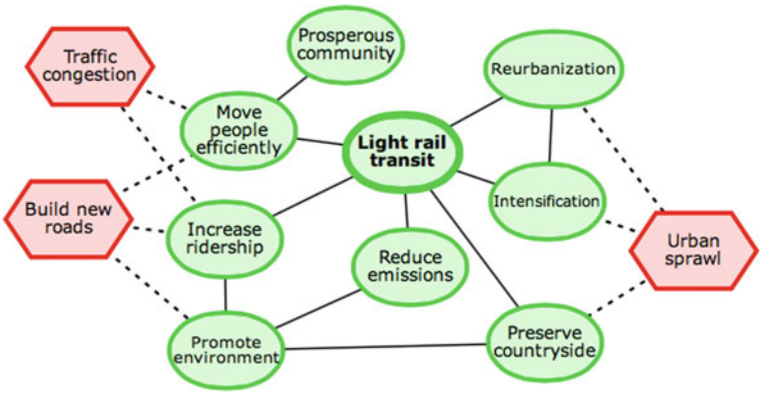

Fig. 11.4 Cognitive-affective map of the values supporting light rail transit in the Waterloo Region, based on http://rapidtransit.regionofwaterloo.ca/en/. The *ovals* indicate strong support for light rail transit

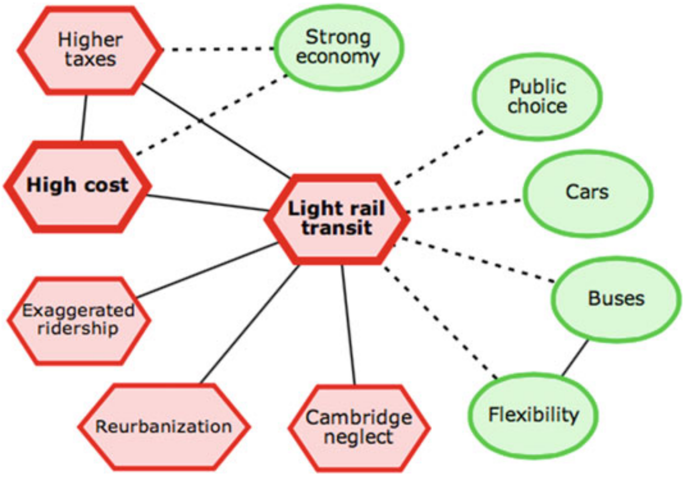

Fig. 11.5 CAM of the values that foster opposition to the light rail transit project in the Waterloo Region, based on the website http://www.t4st.com and another no longer available. The *hexagons* indicate strong rejection of light rail transit

questions such as cost and ridership. The two sides emphasize very different values, such as urban intensification for supporters and low taxes for opponents. Recognizing such differences may lead to the conclusion that the conflict is irresolvable, but it may also encourage people to seek resolution by emphasizing common values, such as enabling a prosperous community.

11.5 Decisions by Emotional Coherence

Cognitive-affective maps are based on the theory of emotional coherence I developed (Thagard 2000, 2006). This theory is an extension of the view that inference is not the kind of serial process assumed by formal logic, but rather a parallel process of maximizing coherence by satisfying conflicting constraints. I proposed that elements in coherence systems such as beliefs and actions have, in addition to acceptability, an emotional valence which can be positive or negative. Depending on what the element represents, the valence of an element can indicate likability, desirability, or other positive or negative attitudes. Elements are related to each other by positive and negative valence constraints unless there is no connection between them. The calculated valence of an element is like the expected utility of an action, with degrees of acceptability analogous to probabilities and valences analogous to utilities.

The basic theory of emotional coherence can be summarized in three principles:

1. Elements have positive or negative valences.
2. Elements can have positive or negative emotional connections to other elements.
3. The valence of an element is determined by the valences and acceptability of all the elements to which it is connected. The kind of acceptability depends on the kind of element, such as taking a belief to be true to judging an action to be worth performing.

This theory is implemented in a computational model called "HOTCO," which stands for "hot coherence," in which units (artificial neurons) have valences as well as activations. Positive emotional connections are implemented by mutual excitatory links between units, and negative emotional connections are implemented by mutual inhibitory links between units. The valence of a unit u_j is the sum of the results of multiplying, for all units u_i to which it is linked, the activation of u_i times the valence of u_i, times the weight of the link between u_i and u_j:

$$net_j = \Sigma_i w_{ij} v_i(t) a_i(t).$$

.

Every CAM can be converted into a HOTCO simulation of emotional coherence by *Empathica* (which generates the required computer code) as follows:

1. Every CAM element becomes a HOTCO unit, capable of acquiring positive or negative valence.
2. Every solid line (coherent link) between elements in CAM becomes an excitatory link between the corresponding HOTCO units.
3. Every dotted line (incoherent link) between elements in CAM becomes an inhibitory link between the corresponding HOTCO units.

The major difference between the HOTCO simulations and the CAM method is that the latter only displays the results of a calculation of emotional coherence, whereas HOTCO actually carries out the computation; CAMs display the static result of the dynamic process of computing emotional coherence performed by HOTCO.

Emotional coherence explains why different planners make different decisions, because of their initial emotional values and how they apply in particular contexts. Suppose the question is whether to build a freeway through an established neighborhood, an issue that Jane Jacobs tackled in New York City in the 1950s and in Toronto when she moved there in the 1960s. It is obvious that building a freeway is coherent with the values in Fig. 11.2 such as automobiles, but not with the values in Fig. 11.3 such as neighborhoods. In both New York and Toronto, Jacobs was successful in limiting freeway expansion. Similarly, the decision not to bring major roads into the city centre of Delft is based on coherence with the values shown in Fig. 11.3 rather than those in Fig. 11.2. The values Fig. 11.4 such as preserving countryside support the judgment that building a light rail network is the most emotionally coherent choice for the Waterloo Region, but the values in Fig. 11.5

such as facilitating cars support the opposite conclusion. In 2014, Waterloo Region went forward with light rail transit, reflecting the values of most political leaders and the general population.

11.6 Cognition, Emotion and Semantic Pointers

Brains are much more complicated than the small networks of neurons representing concepts and propositions used in the HOTCO model. Chris Eliasmith, my colleague at the University of Waterloo, has published an amazing book, *How to Build a Brain* (2013), that suggests a new way of thinking about how mental phenomena can be explained by neural mechanisms. He also synthesizes the dominant historical approaches to cognitive science, which we can sketch out as follows:

Thesis (1950s): Thinking results from the manipulation of physical symbols like those that operate in digital computers.

Antithesis (1980s): Thinking results from the interaction of large numbers of neurons that excite and inhibit each other without any explicit manipulation of symbols.

Synthesis (2013): Thinking results from neural processes that can function as symbols.

Cognitive science developed rapidly in the 1950s with the insightful idea that new ideas about computing could serve as a model of how thinking works as a mechanical process. This idea was a major improvement over previous analogies such as clockwork (1600s), vibrating strings (1700s), and telephone switchboards (early 1900s), and generated many important psychological insights about problem solving and language. But there remained many unsolved problems in psychology and artificial intelligence, such as how purely computational symbols could have meaningful relations to the world.

In the 1980s, the connectionist approach proposed that the functioning of neural networks provides a better model for understanding how the mind works to make inferences and understand the world. Representations in neural networks do not look like symbols in natural language or computer programs because they are distributed across many simple neuron-like entities that interact with many others. Processing is a highly parallel process, requiring the simultaneous firing of many neurons, unlike the serial step-by-step inferences that occur in linguistic arguments and most computer programs. Connectionism generated valuable insights about psychological processes—such as their use of parallel processes and representations distributed across many neurons—but had difficulty explaining the high-level symbolic reasoning that is also part of intelligence.

Eliasmith's new book provides the first plausible synthesis of symbolic and connectionist approaches to cognition. He proposes (2013: 78) the novel hypothesis of semantic pointers, which are "neural representations that carry partial semantic content and are composable into the representational structures necessary to support complex cognition." As in connectionism, semantic pointers are patterns of firing in large neural populations, but, in Eliasmith's theory, they also function as symbols in high-level reasoning. His book presents the Semantic Pointer Architecture (SPA), which describes how neural structures and processes can generate many kinds of psychological functions, from low-level perception and action generation to high-level inference such as ones measured in intelligence tests. In my own work, I have found the semantic pointer idea to be wonderfully suggestive for developing new theories of intention, emotion and consciousness (Schröder et al. 2014; Thagard and Schröder 2014; Thagard and Stewart 2014).

Eliasmith's semantic pointer representations are useful for understanding cognitive processes in urban planning because:

1. They can handle non-verbal representations that are visual, auditory, tactile and kinesthetic, all of which are patterns of firing in groups of neurons. These representations are all important in representing our perception of urban environments, such as the look of buildings, the sound of cars, the touch of fabrics and the feel of opening a door.
2. Semantic pointers allow representations that are both symbolic and embodied.
3. Semantic pointers can include bindings of cognitive representations such as ideas and beliefs with representations of emotions: they show how values such as those in Figs. 11.2 and 11.3 can enter into emotional decisions. Here binding is a process that combines neural representations (patterns of firing) into new ones.

For example, the concept of a city can be viewed as operating in the brain as a semantic pointer that results from binding together verbal information (e.g. a city as a kind of social organization), visual information (the perception that the buildings are tall), auditory information (such as traffic noise) and emotional information (that cities are exciting, and/or dangerous). Such complex representations can contribute to verbal inferences and complex decisions involving emotional coherence.

11.7 Social Processes and Mechanisms of Emotional Transmission

Urban planning is usually carried out by groups of people; the interactions of people affected by urban planning are social processes. Hence emotional cognition requires attention to social processes as well as individual, psychological ones. The social processes of emotional transmission among persons include: molecular communication, e.g. the smell of fear; mirror neurons that fire in response to other people's behavior; emotional contagion by mimicry of facial expressions; attachment-based learning from parents and other mentors; altruism, sympathy and empathy; social cuing, where the emotions of others prompt different emotions in the perceiver; power manipulations; and propaganda (Thagard 2015a).

The best way to model the interactions of psychological and social systems is to use agent-based modeling where the agents engage in emotional cognition and the processes of interaction include transmission of emotions such as those outlined above. HOTCO has been extended to include simple kinds of emotional transmission among agents who take decisions according to emotional coherence (Thagard 2006, 2012b). It would be useful to simulate the group decisions and negotiations that go into urban planning using an agent-based model of emotional communication and decision-making. Researchers in Berlin have produced an adaptation of HOTCO that provides an illuminating account of the processes involved in changing the public's minds about the use of electric vehicles in Germany (Wolf et al. 2015). In the following section I take these insights further to focus specifically on the issue of encouraging creativity in cities.

11.8 Social Simulation of Creativity

Urban designers are currently interested in finding ways to foster creativity in cities, and they place an important emphasis on the important role that cities themselves play in the process. I count as creative a product—such as an urban plan or social service—that is new (novel, original), valuable (important, useful, appropriate, correct, accurate) and surprising (unexpected, non-obvious) (Boden 2004; Simonton 2012). Florida (2005) has described how vibrant cities can bring people together in ways that increase their individual and collective creativity. Creativity is not a purely cognitive phenomenon independent of emotion, because creative people—including a broad range from artists to scientists—are fueled by positive emotions such as enthusiasm as well as by negative emotions such as fear of failure. For a discussion of the role of emotions in the work of scientists see Thagard (2006, Chap. 10). On design creativity, see Goldschmidt (2015).

Much less understood is the role that emotions and cognition play in the social processes that help to generate creativity in urban environments. A computational model of social creativity could help to outline the qualities that urban designers can aim for in planning for creative cities. The resulting model has all the properties of complex systems described in the next section, plus the additional capacity of operating at multiple levels; individual creators are complex systems at the psychological and neural levels, and creative groups are also complex systems at a higher level—a system of systems. Many complexity theorists have noted the importance of multilevel operations in complex systems (Findlay and Thagard 2012; Thagard 2012a; Alexiou 2010).

Although I have not yet produced a social simulation of creativity, I outline the design for one in what follows with reference to previous computational models. My first multilevel simulation was the CCC (consensus = communication + coherence) model of scientific consensus (Thagard 2000, Chap. 7). In this model, individual scientists are simulated as evaluating hypotheses with respect to evidence by assessing explanatory coherence using the ECHO neural network algorithms for inference to explanatory hypotheses (Thagard 1989, 1992). Each scientist can make his own evaluation of what hypotheses to accept given the available evidence, but CCC adds a social dimension by allowing scientists to exchange evidence and hypotheses. When two scientists meet randomly in the model—as at a conference—they exchange evidence and hypotheses. After these exchanges, each scientist re-evaluates the acceptability of their hypothesis based on the enlarged set of hypotheses and evidence. When simulated scientists interact and "change their minds" in the CCC model, hypotheses that were previously accepted become rejected and hypotheses that were previously rejected become accepted. Consensus is reached when all scientists in a community accept the same hypotheses as in simulations of reaching consensus in two scientific cases: determining the causes of ulcers and the origin of the moon (Thagard 2000). This kind of social simulation involves agents that are much more complicated than the simplistic ones in most agent-based models. The agents in CCC show complexity in their capability to reason about hypotheses and evidence.

Nevertheless, CCC falls short of being able to model social creativity. First, individual scientists in it are only able to evaluate and communicate hypotheses provided to them, with no capacity to generate new hypotheses or the concepts that are used to construct them. To introduce creativity, the program would need algorithms that enable the agents to form new concepts and hypotheses such as those found in my earlier PI model (Thagard 1988). Second, CCC ignores the role of emotions in scientific thinking.

I introduced emotions into computer simulations in my HOTCO models (Thagard 2006). Initially, HOTCO—for Hot Coherence—applied only to individuals. In it, representations of actions and goals as well as hypotheses and evidence were capable of possessing emotional valences as well as acceptability. However, in HOTCO 3 I added the capacity of simulated agents to exchange valences, goals and actions just as the scientists in CCC could exchange hypotheses and evidence. Simulations with HOTCO 3 showed that groups of decision-makers could achieve emotional consensus when all agents arrived at similar valences through the exchange of information, resulting in agreement about their individual decisions. HOTCO 4 enhanced HOTCO 3 by taking into account the role of special subgroups in group consensus and polarization (Thagard 2012b).

In order to expand HOTCO 3 and 4 into HOTCO 5—a version that would have the capacity to model social creativity—some new ingredients, sketched out below, are crucial. First, the representation of creative products needs to go beyond the symbolic representations used in HOTCO, because creativity can involve non-verbal representations such as visual, auditory and tactile images (Thagard 2015a). Because vectors (lists of numbers) can be used as stand-ins for all sensory inputs and images, HOTCO 5 should be able to store and manipulate vectors. I am not proposing that human brains use vectors, but rather exploiting the methods developed by Eliasmith (2013) for translating any vector into patterns of neural activity.

Second, each agent should be capable of generating new vectors by combining two previously existing ones. The idea that creativity results from combining representations has frequently been proposed, originating—as far as I have been able to trace it in the literature—with Stewart (1792; see also Boden 2004). Combinations of vectors should not be simple additions and subtractions, but rather involve a more mathematically complicated operation such as circular convolution (Plate 2003). Convolution into vectors can represent many kinds of information (Eliasmith and Thagard 2001). The translation of vector combination into neural activity has been used to simulate the combination of representations in creative processes, as well as the emotional response (Aha!) that results from such combination (Thagard and Stewart 2011, reprinted in Thagard 2012a). For evidence that all creativity involves the combination of previously unconnected ideas (what I call the combinatorial conjecture), see Thagard (2012a, 2015a, b).

Third, in order to introduce emotions into the vector-combining version of HOTCO, we can use vectors as stand-ins for emotional responses that in reality would be more complicated combinations of cognitive appraisals and physiological perceptions, in line with the theories of emotions proposed by Thagard and Aubie (2008) and Thagard and Schröder (2014). It is easy to do such binding by convolving vectors for cognitive representations, such as hypotheses and actions, with vectors for emotions.

Fourth, we can make HOTCO 5 social by allowing agents to exchange vectors. The vectors exchanged would encompass the full range of cognitive representations, including sensory images (visual, auditory, etc.), as well as the full range of emotional representations. The emotion vectors could include information about positive and negative valences, as in HOTCO 3, but they could also encode specific emotional reactions such as happiness, fear and anger, as long as they were composed by binding (convolving) the full range of components of emotion, including cognitive appraisal and physiological perception.

Fifth, in order to make the social process of communication more efficient, we could use emotions to constrain the exchange of representations. Stochastically, a vector would be more likely to be transferred from one agent to another if it included an emotional representation corresponding to enthusiasm or any other positive reaction. In other words, one agent would be more likely to pass an idea onto another if the donor agent is enthusiastic about the idea. Like its predecessors, HOTCO 5 would be a highly complex multilevel system, a system of systems each of which is complex. But what does complexity mean in this context?

11.9 Complexity and Emotional Cognition

Cities and urban environments are clearly complex systems, but little work has been done to integrate complexity ideas (sometimes elevated to the status of a theory or science) with cognitive and affective ideas (but see Gray 2012). Below I sketch out an approach to integrating these.

11.10 Why Complexity Theory Needs Cognitive Science

Ideas about complexity that are applicable to our models include state space, attractors, chaos, feedback loops, tipping points (critical transitions), self-organization and emergence. But these ideas remain at the level of vague metaphors unless they are specified in terms of variables and equations; many of the relevant variables and equations for explaining human systems concern mental states and processes, which cognitive science explains using rigorous models that are mathematically precise enough to be implemented in computer simulations.

11.11 Why Cognitive Science Needs Complexity Theory

All computational cognitive models implicitly have state spaces and attractors, but many ignore chaos, feedback, tipping points and emergence. The major exceptions are neural networks, which display all of these features although they are rarely mentioned. More explicit use of this terminology can facilitate communication with people in other fields who routinely describe systems using complexity terminology. Cognitive science also needs to get better at dealing with interactions between multilevel systems, including social, neural, and molecular systems as well as psychological ones.

11.12 Translations

1. *State space*. In psychological cognitive models, the key variables are properties (such as acceptability) of mental representations (such as concepts and beliefs). The equations specified in computer programs describe how these variables change values as the result of changes in inputs and internal interactions. In neural models, the key variables are properties assigned to artificial neurons, such as firing rates. Equations indicate how the firing of one artificial neuron changes because of inputs from other neurons in the model.
2. *Attractors and self-organization*. If a psychological model has multiple stable states that it can move among, depending on sensory inputs and stored information, then these states can be described as attractors. All neural models, which store information by synaptic connections, have such attractors, and all can be considered self-organizing in the sense that global order and coordination arise out of local interactions.
3. *Chaos*. All neural network models are highly sensitive to initial conditions, showing dramatic changes in response to small inputs, and a few psychological cognitive models (e.g. for spreading activation) are also chaotic.

4. *Feedback loops*. All neural network models have amplifying (positive) feedback loops resulting from excitatory connections and dampening (negative) feedback loops resulting from inhibitory connections. The usual terms for such loops are "reentry" and "recurrent".
5. *Tipping points*. All neural network models display tipping points when they move from one stable state (attractor) to another. The most important tipping points in individual humans are shifts in systems of beliefs and attitudes, which are easily modeled by HOTCO. The most important tipping points in societies are shifts in the beliefs and attitudes that are shared among groups.
6. *Emergence*. An emergent property is one that belongs to a whole rather than to its parts: it is not just the aggregate of properties of the parts because it results from the interactions of these (Findlay and Thagard 2012). Neural systems have such properties; representation (standing for something) is an emergent property of a population of neurons. Likewise, I think that consciousness is an emergent property of interacting neural populations (Thagard and Stewart 2014). Analogously, I conjecture that creative groups have emergent properties in the form of new, valuable and surprising ideas that would not develop without social interactions.

11.13 Conclusion

I have tried to show some of the ways that new ideas about cognition, emotion and group processes are relevant to urban planning. To do so, I have described the role that values play in decisions about cities, and shown the relevance of cognitive-affective maps and emotional coherence to understanding such decisions. Cognition and emotion also contribute to social processes such as group planning and collective creativity. Ideas about complexity have been fleshed out by indicating how neural and social networks display behaviors attributed to complexity, such as chaos, attractors and tipping points. I hope that better cities can result from a deeper understanding of the cognitive, affective and social processes that contribute to urban planning.

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Part IV
Complexity, Cognition and Design

Chapter 12
A Complexity-Cognitive View on Scale in Urban Design

Egbert Stolk and Juval Portugali

Abstract Urban designers 'design across scales', moving between streetscapes, neighborhoods and entire cities or regions. In this paper we study the urban design process from a conjunction between perspective of Synergetic Inter-Representation Network (SIRN) and Construal Level Theory (CLT). The first refers to a sequential process of interaction between internal representations constructed in the mind ~ brain and external representations (e.g. the design media) constructed in the world; the second refers to the process of abstraction in terms of psychological distance. Our SIRN-CLT view on scale in urban design sheds new light on the relations between the scale of the design object, the design medium and the design process. We show that urban design deals with hybrid large-scale and complex design objects. An example from the domain of urban design is given to illustrate is view.

12.1 Introduction

In two previous studies we've described design processes in terms of a conjunction between theories of complexity and cognition (Portugali and Stolk 2014; Stolk and Portugali 2012). From this perspective, design is portrayed as an ongoing interplay between internal representations constructed in the designer's mind and external representation constructed by the designer in the world. We term this process SIRN (Synergetic Inter-Representation Network)—a term derived from *IRN*, which refers to the interplay between internal and external representations, and *Synergetic*, as

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explained by Haken's 1983 theory of complex, self-organizing systems indicating that design evolves as a complex self-organizing process.

Although the interplay between representations portrays the general design process, in practice the details of the SIRN process differ when designing objects at different scales. As we show below, design objects at different scales imply, first, different cognitively embodied relations between the designer and the object and as a consequence activate different cognitive properties and capabilities of the designer. Second, they imply the need to engage different external representations, which in the process of design refers to different design media. Third, they imply a distinction between two types of design objects: closed-simple design artefacts (e.g. a chair) and open-complex design artefacts (e.g. a city).

This dependency of the SIRN design process on variations in the scale of objects requires deeper understanding of the role of scale. In this paper, we suggest Construal Level Theory (CLT) as a means to explore the properties of internal and external representations of various scales associated with the design process and the implications thereof to the resultant designed artefacts. CLT's main concern is the relation between levels of abstraction and psychological distance, which adds new insight to our understanding of scale variations in the process of design and more specifically on the process of urban design dealing with open-complex design artefacts.

The discussion below starts with an outline of SIRN (Sect. 12.2) and a short discussion on scale in design (Sect. 12.3). Section 12.4 introduces CLT and elaborates its connection with scale and the design medium, while Sect. 12.5 studies the implications of CLT to scale in SIRN design processes. In Sect. 12.6, we relate the CLT view on scale in design to the nature of the design object—as closed-simple or open-complex design artefact—drawing on an example from urban design. At the end of the paper (Sect. 12.7) some conclusions are drawn with respect to urban design and to CLT.

12.2 SIRN Design Processes

12.2.1 SIRN and Its Submodels

The notion of IRN refers to cognitive processes that cannot be implemented by a single cognitive act and thus evolve as a sequential interaction between internal representations constructed in the mind ~ brain and external representations constructed in the world. Some of these processes are rather mechanical, such as the multiplication 465×937, while others are creative—making use of the complexity of the human cognitive system and its abilities to think and imagine. Haken and Portugali (1996) have termed such processes SIRN. see Fig. 12.1.

In two previous papers (Portugali and Stolk 2014; Stolk and Portugali 2012) we suggested, that, because the designer can be seen as a cognitive agent, design processes can be understood in terms of SIRN: design as a sequential interaction between internal representations constructed in the mind ~ brain of the designer and

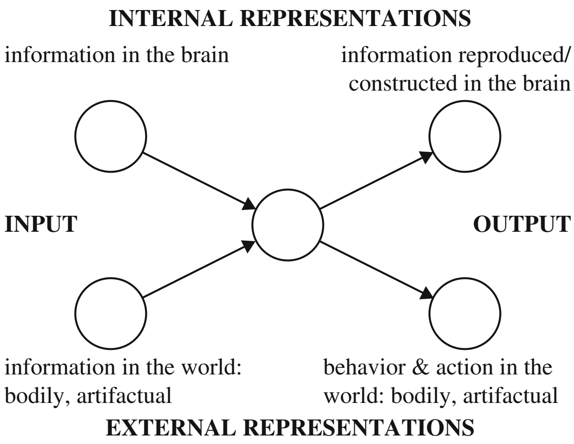

Fig. 12.1 The basic SIRN model, as derived from Haken's synergetic computer. The diagram represents a self-organizing agent that is subject to two forms of information; internal and external, and is actively constructing two forms of information, again internal and external. *Source* Haken and Portugali (1996)

external representations constructed by them in the world. We also elaborated several models of typical design processes in line with SIRN, which, as explained below and illustrated in Fig. 12.2, refer to the scales of an individual designer (a), to a sequence of designers (b), and to a group of designers (c):

(a) The *Intrapersonal design model* (Fig. 12.2, *top left*) is typical of a single solitary designer working by means of interplay between ideas internally constructed and represented in mind, and sketches externally represented on paper.
(b) The *Interpersonal-sequential design model* (Fig. 12.2, *bottom left*) is typical of a sequence of designers where the externally represented outcome of a

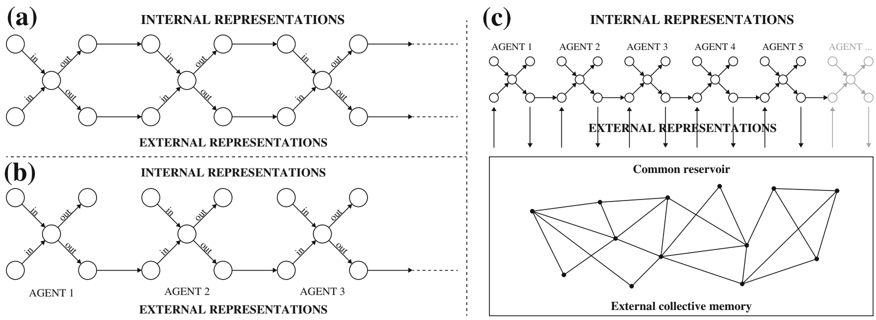

Fig. 12.2 Three SIRN sub models: **a** the intrapersonal model, **b** the interpersonal–sequential model, and **c** the interpersonal–simultaneous model

Table 12.1 Overview of fast and slow SIRN design processes

SIRN design process	Fast design process	Slow design process
Intrapersonal	Series of representations of an artefact by a single designer: series of sketches.	Series of realized artefacts by a single designer: oeuvre.
Interpersonal	Sequence of representations of artefacts by different designers.	Sequence of realized artefacts by different designers.
Collective	Simultaneous realization of representations of artefacts by different designers: a model for collective urban design processes.	Simultaneous realization of artefacts by different designers: a model for urban dynamics.

designer's design object influences a second designer's imagination (internal representation) that in turn produces a second design object, and so on.

(c) The *Interpersonal-simultaneous model* (Fig. 12.2, *right*) refers to the urban dynamics through which the external representation is the city as a whole and the urban agents (as designers) interact with the city as it evolves; it makes specific reference to Ekim Tan's recently developed *Play the City* design approach that uses this model as a basis for a practical collective negotiation of the urban design process (Tan 2016; Tan 2014; Tan and Portugali 2012).

12.2.2 Fast and Slow SIRN Design Processes

Building on our earlier work on SIRN, this paper proposes a further distinction between 'fast' and 'slow' SIRN design processes (Table 12.1). *Fast design processes* take place using different design media and represent typical design processes in which sketches and drawings are used, resulting in a representation of the design artefact before its actual production. *Slow design processes*, by contrast, include several fast SIRN design processes and describe the evolution of designed artefacts based on the actual realization of a sequence of designed artefacts.

The notion of 'representation' that forms the core of SIRN is rather general and abstract. The practice of SIRN design processes depend on the design medium, scales, and level of abstraction.

12.3 Scale in Design

Writing about the meaning of scale in geography, (Montello 2001, 13501) notes that "The concept of scale can be confusing, insofar it has multiple referents" such as the interrelated *cartographic scale*, *analysis scale* and *phenomenon scale*. Extending Montello (2001) and applying his view to our domain of design, we suggest that different levels of scale in design are associated with four different referents. First, it is associated with design objects of differing *scale-sizes*, ranging from small objects we can hold in our hands to the very large objects such as cities, or even systems of cities. Second, it is associated the *scale properties* of the designed entity; here, the distinction between scale-free properties and scale-dependent properties becomes relevant. Third, it is associated with the scale of the *design medium*: the relation between the size of the designed object and the size of the design medium, be it a sketch, plan, drawing or mock-up. Fourth, it is associated with the resolution or granularity of the representation of the design object and the design medium, which is related to the *level of abstraction*. The first three scale referents are discussed in this section; the fourth will be discussed in Sect. 12.4.

12.3.1 The Design Object

We can best understand the concept of scale by reference to the scale we know best —the scale of our body. Freundschuh and Egenhofer (1997) discuss the properties of different spaces derived from an extensive literature study, and related to several scales, by systematizing them according to the relation of each space to the human body. Their classification is based on manipulability, locomotion and size, and results in six types of spaces:

1. *Manipulable object space*—comprises very small-scale objects, which can be rotated by our body and which do not require locomotion to experience them;
2. *Non-manipulable object space*—consists of non-manipulable, small-scale objects requiring locomotion to experience them;
3. *Environmental space*—includes non-manipulable, large-scale objects that require locomotion to experience them.
4. *Geographic space*—covers very large, non-manipulable spaces that due to practical limitations cannot be experienced via locomotion.
5. *Panoramic space*—encompasses non-manipulable, small- to large-scale spaces that to not require locomotion to experience them.
6. *Maps space*—covers the symbolic representations of the different spaces whose general intent is to reduce and simplify spatial information and to present it in a manageable form.

The above can be divided into two main classes: *small-scale objects* (1, 2 and 5) and *large-scale objects* (3, 4 and 5) that differ in the way humans visually and bodily experience them. Small-scale objects are objects that can be seen in their entirety such as a pen, a laptop, a chair, a desk and so on. In the daily visual and bodily experience, we look at and interact with such objects from the outside. Large-scale objects cannot be seen in their entirety; since they are (much) larger than the human body, our usual visual experience is that we look at them from the inside. When visualizing such objects from the inside, we see bits and pieces that can be likened to a puzzle *that can either be completed in time or remain incomplete*. Large-scale objects can thus be further divided into two qualitatively distinct types of environmental space: the first is the space for which we can complete the puzzle in time, like the space of an apartment or a building. The second is the type of spaces that will remain unsolved or incomplete, such as a neighborhood, a city, a forest or a park. Figure 12.3 shows the conjunction between Freundschuh's and Egenhofer's classification and our extension of it as described above.

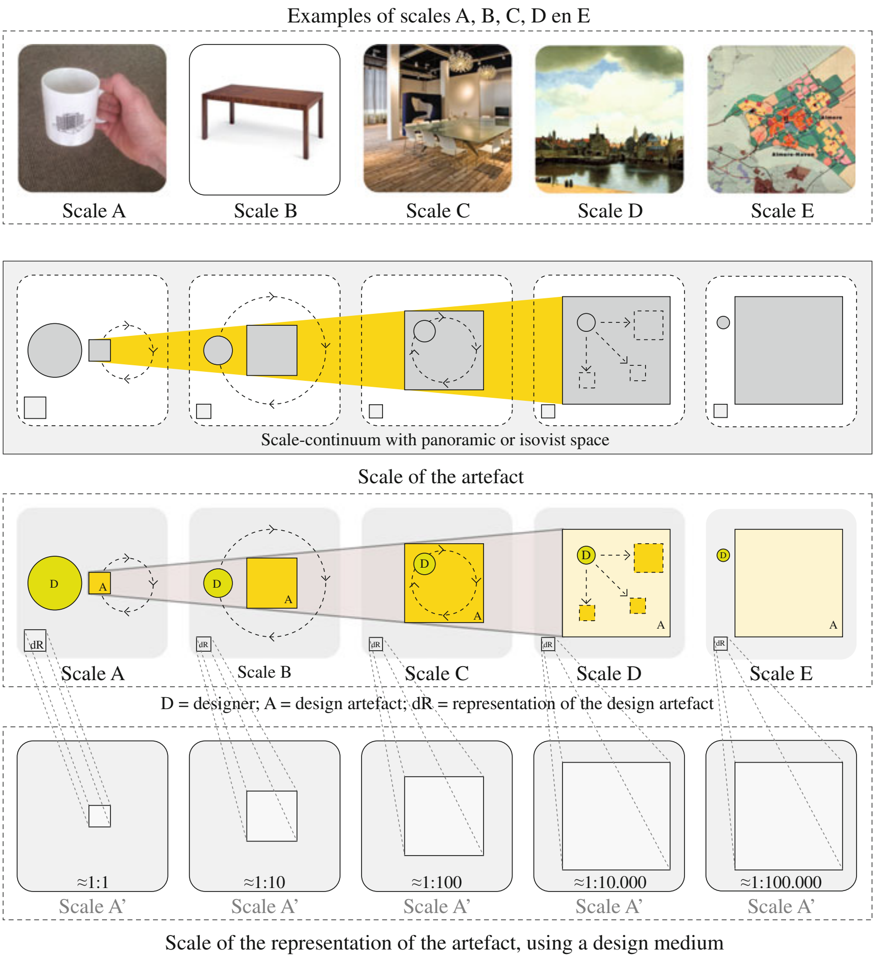

Fig. 12.3 A design interpretation of Freundschuh and Egenhofer's spaces: **a** the manipulable object space—objects rotatable by our body; **b** the non manipulable object space—objects we need to move around to get a full impression; **c** environmental space—which can be explored completely in time; **d** environmental space/geographic space—which cannot be explored completely because of its scale; and **e** geographic space, which is not explored at all. Additionally the *grey* zone represents the panoramic space or isovist space, visually linking different types of spaces and scales. D stands for Designer; R for design Representation (map space); A for designed Artefact

12.3.1.1 Cognitive Maps

How do designers deal with these large-scale design objects? The answer is simple: like humans in general—by means of *cognitive maps*. Following Tolman's (1948) seminal paper on 'cognitive maps in rats and men' and many subsequent studies (see Portugali 2005) we now know that animals and humans have the cognitive capability to construct out of these experiential puzzle pieces a *cognitive map*, that is, an internally represented image of their environment. In the context of our present discussion, this can mean an internal representation of a building, a neighborhood, a city or a forest. As we move through our environment, more and more puzzle pieces are added to our memory from which, when needed, we construct an add-hoc, task specific cognitive map (Portugali 1996). Cognitive maps are thus never completed and are not accurate representation of the environment, as shown time and again by studies on systematic distortions in cognitive maps (Tversky 1992). The significance of cognitive maps is that human agents, including designers, behave and act in and on the environment according to these maps.[1]

From the above follow two forms of design processes: those producing small-scale artefacts and those producing large-scale ones. In the first process, the designer has the capability of observing the artefact in its entirety, from the outside, and can thus follow the artefact as it is changing and evolving during the design process. This process is typical of craftsmanship and artistic work. In the second, the designer cannot see the artefact in its entirety as it is developing, but *only* imagine it by means of cognitive maps, and by means of design media—sketches, computer visualization devices and the like.

12.3.1.2 Designing Across Scales

If we look around, we can observe objects of a variety of scales co-existing simultaneously: a scale A object (coffee-cup) on top of scale B object (table), within scale C objects (room, house) while looking outside to a scale D object (the city), in the context of unexplored spaces (scale E). These objects and spaces are part of the panoramic space, which changes continuously when we move around in space (see Fig. 12.2). Depending on the design domain, designers tend to focus on either one specific scale or at a range of different scales simultaneously.

Urban design mainly focuses on large-scale spaces (C, D and E). Urban designers typically work on these various scales simultaneously. In doing so, they *design across scales* (Bekkering 2013). For example, on one scale they might focus on the design of a specific public space (scale C), while at another scale the network of public spaces in the city as a whole is considered (scale D), in the context of

[1]In fact, SIRN's general model and its three submodels were originally developed in order to describe the process of cognitive mapping (Haken and Portugali 1996; Portugali 1996).

unexplored spaces (scale E). In the design process, urban designers switch between those scales to create *coherence*[2] across them.

12.3.2 Scale-Free and Scale-Dependent Design

In moving across different scales, designers can employ two design approaches: *scale-free design* and *scale-dependent design*. *Scale-free design* is typical to design in which a given design principle is applied to the various scales of the designed object. The notion of scale-free accompanies (albeit implicitly) the study of cities since the early twentieth century (Auerbach 1913; Christaller 1966/1933); Lösch 1954), while today is central to complexity theories of cities (Batty 2013; Portugali 2011). It is therefore no surprise that it has also been applied to urban design. The typical example is an urban design solution that starts, say, with a set of neighborhoods, each with it own center, making up a city with a major city center, connected in turn—like other cities—to a metropolitan center. This typical pattern results in a hierarchical, nested or tree structure: a scale-free structure. Scale-free design is typical also to the recent *parametric* (or *algorithmic*) *design* approaches and the attempts to apply Mandelbrot's fractal geometry and principles to design. Christopher Alexander's seminal paper "A city is not a tree" criticizes this kind of design approach (Alexander 1965).

Scale-dependent design is typical of design in which the transition from scale to scale involves a qualitative change in the design principles applied to the designed object. A typical example in urban design is "A pattern language" (Alexander et al. 1977). In this seminal book, 253 patterns are classified according to three different scales: towns, buildings and construction. Each of these patterns represents qualitatively different design principles, which are directly related to higher or lower scale patterns. This results in a scale-dependent structure.

12.3.3 The Design Medium

The origin of design is commonly ascribed to craftsmanship, a view typified by the designation of design as a craft or 'direct design'describing processes where the designer works directly on the artefact. The introduction of drawings into architectural design (probably in the middle of the fifteenth century) marks the emergence of indirect or 'mediated' design, and with it the question of what the appropriate design medium and scale might be. Of relevance here is McLuhan's influential work *Understanding Media: The Extensions of Man*, which included his famous aphorism "*the medium is the massage*" (Strate and Wachtel 2005); the

[2]see Chap. 11, this volume.

design medium has a profound impact on the design outcome. Several studies have demonstrated that *freehand sketching* supports shifts between figural and nonfigural aspects in the design process, and as such stimulates discovery and creativity (Goldschmidt 1991; Tversky, Chap. 13, this volume; Tversky 2011). On the other side of the spectrum, *CAD systems* tend to stifle the development of ideas in the design process (Mallgrave 2010).

The scale of the medium is determined by the relations between the designed object and the human body: when dealing with large-scale objects that are much larger than the human body (building, neighborhood, city or region), the medium is of smaller scale relative to the object, whereas when designing a very small object relatively to the body, like a ring, the medium is of a larger scale relative to the object. Some design representations are *scale-dependent*; others are *scale-free*. Freehand sketching is used on various scales (A-E), and can be considered to be a scale-free design medium. GIS systems are typically limited to the large environmental scales and geographical scales (D and E).

12.4 A CLT View on Abstraction in Design

The notion of abstraction is central to design (Protzen and Harris 2010), and is recognized as essential to urban design as well (Caliskan 2013). In any design process, designers move back and forth between abstract and concrete information, beginning in most cases with an abstract idea (a concept, parti or guiding theme), which is then unfolded into a concrete design. This process is characterized by several jumps—mental leaps and iterations—which can be described as a SIRN process (Stolk and Portugali 2012). This section discusses abstraction from the perspective of Construal Level Theory (Trope and Liberman 2010), focusing on the notions of scale and design media, as well as their interrelation.

12.4.1 Construal Level Theory (CLT)

People experience themselves in the here and now, but consider, evaluate and plan situations that are in many respects far away. These situations require a mental construct to bridge this distance. Trope and Liberman's (2010) Construal Level Theory (CLT) describes the relation between psychological distance and the extent to which people's thinking is abstract or concrete. In general, the idea of CLT is that distant objects are thought of as more abstract than close objects, which we perceive as being more concrete. Different types of dimensions influence this *psychological distance*. The main dimensions studied are: distance in time, such as the recent or distant past or future; distance in space, near or far; and social distances, close or distant from the social group.

Fig. 12.4 Psychological distance: spatial distance in conflict with social distance. After Liberman and Trope (2008)

CLT holds that the further away an event or an object is from our direct sensory experience, the more abstract the mental construct we create of it becomes. Trope and Liberman's research has shown that different types of distances: have strong relationships; affect and are affected by the degree of abstraction; and affect predictions, preferences and actions.

The strong interrelation of two dimensions of psychological distance is illustrated in Fig. 12.4. The image evokes a conflict: people tend to couple far away with 'they', and close by with 'we', whereas the image reverses this tendency—surprising its 'reader.' CLT provides an explanation for this discomfort: we connect social distance with physical distance—near in spatial terms connects you with what is socially close.

When the distance from our direct sensory experience increases so does the degree of abstraction in which it is thought of. Low-level construal is concrete, relatively unstructured, incoherent, and highly context dependent—likely to include various details and accidental events or objects. High level construal is a more abstract mental construction of an object or event that is further away and not directly observable—it is more diagrammatic, coherent, and less dependent on context, explicit scales and accidental events. This does not mean that higher-level construal is only a reduction of lower levels; it often contains additional information that is complementary to low-level information because abstract thinking enables us to make different (types of) connections.

So, what can CLT tell us about scale, design media and their interrelations?

12.4.2 A CLT Perspective on Scale

The notion of scale is mostly implicit in CLT studies, but appears explicitly in one study; Maglio and Trope (2011) studied the relation between scale and construal level. They describe scale in terms of the resolution of an external representation, and study how this impacts the internal representation of the given entity. Using larger units of measurement (implying a lower resolution, thus a higher scale) results in a higher psychological distance on both spatial and temporal dimensions, and in abstract action identification. The study suggests that high scale is related to high-level construal, and low scale to low-level construal.

In conjunction with other CLT studies, this relationship between scale and construal is highly likely to be bidirectional (Trope and Liberman 2010). Thus, not only are large-scale entities described using more abstract language and more abstract descriptions than smaller-scale ones, but they also trigger a higher psychological distance on both spatial and temporal dimensions.

12.4.3 A CLT Perspective on Design Media

In design processes, designers use a variety of design media—external representations of the emerging design artefact. These design media play an important role in SIRN-processes.

An interesting CLT study related to design media was conducted by Amit et al. (2009). They studied the level of abstraction of two different types of representation: words and pictures. Their research shows that people tend to prefer using pictures to represent proximal events and words to represent distal events, suggesting that, "the two modes of construal have crystalized into dedicated means of representation" (ibid, 54), in line with the dual-coding approach (Paivio 1986). In general, pictures are concrete and context-bound, while words are more abstract and generalized.

While Amit et al. consider the difference *between* words and pictures, they do not take into account the variety of levels of abstraction *within* these two modes of representation, as both words and pictures can denote more abstract or concrete features. For example, a diagram or a sketch are by their very nature more abstract and as such tend to have high construal level features compared to, for example, photographs or technical drawings, which by their nature are highly realistic and concrete. From this distinction follow significant implications regarding the transition in recent years from design by means of sketching to design by means of computer graphics and visualization.

12.4.4 CLT, Scale-Distance and Design Medium-Distance

From a CLT perspective, we can construct the general relation between scale and abstraction: bigger scales trigger higher-level and thus more abstract internal representations (Henderson and Wakslak 2010; Maglio and Trope 2011). The external representations of these internal representations can be more concrete or abstract

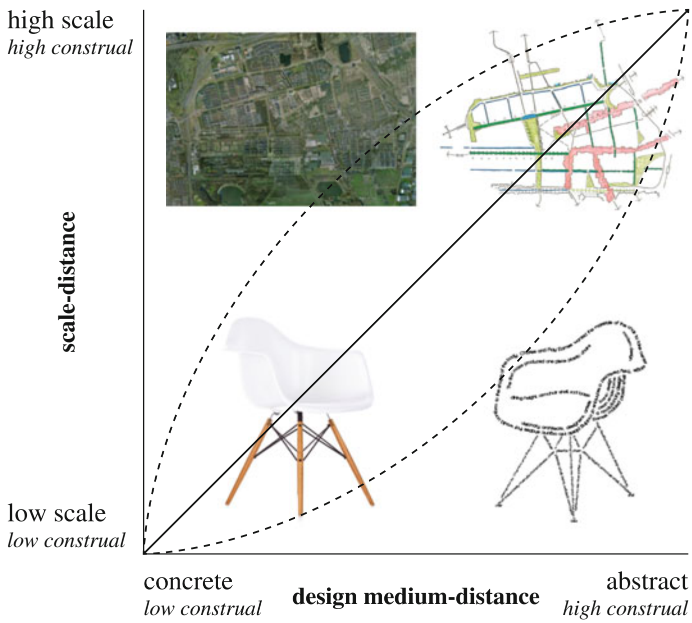

Fig. 12.5 Scale distance and design medium-distance. The *dotted line* roughly represents the relation between the scale-distance and the design medium-distance

(Amit et al. 2009; Maglio and Trope 2011). We propose calling these dimensions: *scale-distance* and *design medium-distance.*

These dimensions are illustrated in Fig. 12.5. The photograph of the DAW chair by Eames is a concrete representation on the scale of ~ 1:20, whereas the artistic interpretation[3] is an abstract representation on the same scale. The aerial photo of Ypenburg[4] is a concrete representation on the scale of ~ 1:50:000, whereas the drawing by Frits Palmboom[5] is an abstract representation on the same scale. Nevertheless, the aerial photo of Ypenburg is a more abstract representation in comparison to the photograph of the Eames chair because of the scale it depicts.

In this context, it is interesting to consider the perception of time in scale model environments, as these are used frequently as a design-medium in urban design processes. Mitchell and Davis (1987) showed that using scale models of environments has an impact on the perception of time: time is compressed related to differences in the density of the information to be processed in environments of different scales: the smaller the scale, the higher to compression of time. These findings are in line with the findings of CLT research.

[3]An interpretation of the DAW chair by Sarah Schmidt (sarahschmiddesigns.com).

[4]maps.google.com.

[5]palmbout.nl.

12.5 A SIRN View on Scale and Abstraction in Urban Design

This book as well as its first chapter (Portugali, Chap. 1, this volume) opens with a dilemma: A city is a large-scale collective artefact; artefacts are, by definition, simple systems; so what is it that makes the city complex? Following the first chapter, our answer is that cities are hybrid complex systems, composed of simple systems (artefacts) and complex systems (human agents) and that it is due to the latter that cities are complex. This view on cities raises questions regarding the design objects and design media that are the focus of this article and thus questions regarding the SIRN design process as a whole: Design objects and media are essentially artefacts; are they simple or complex (Sect. 12.5.1)? How do design media relate to the various levels of scale and abstraction (Sect. 12.5.2)? And finally, what are the implications to the complex system SIRN design process (Sect. 12.5.3)?

12.5.1 Complexity, CLT and the Designed Object

In Sect. 12.3 above, we made a distinction between small-scale and large-scale design objects—‘small’ and ‘large’ relative to the (designer’s) human body. CLT adds to this distinction that small-scale objects are psychologically close and concrete, while large-scale objects are psychologically distant and abstract. Complexity theory further adds that small-scale design objects are simple systems, while large-scale design objects such as cities are hybrid complex systems (see Fig. 12.6). Designing across scales implies moving between small-scale, psychologically close or simple design objects, and large-scale, psychologically distant or hybrid complex design objects.

This distinction is made visible in the ability or non-ability of the designer and his/her design process to control the outcome of the design: to control the design object as a whole. In the design of a small object such as a spoon or a chair, the designer can control the final form and properties of, and thus fully complete, the designed object. This is possible since during such a design process, the designer

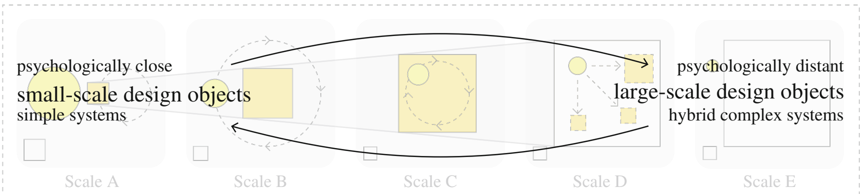

Fig. 12.6 Designing across scales

can, temporarily, isolate the designed object from its environment, and users. In contrast, a designed city is always incomplete—its final properties are determined not by any one professional urban designer but rather in conjunction with a whole host of other designers, such as architects and the city's users as latent designers.

12.5.2 Complexity, CLT and the Design Medium

Design, as noted in Sect. 12.3.3, is usually a mediated process. With the exception of 'direct design,' exemplified by craftsmanship, the designer normally uses various media in the design process. As noted above (Sect. 12.4.4), CLT shows that different media are perceived by the designer (and user) as being psychologically closer and concrete, or more distant and abstract (see Fig. 12.5). Complexity theory adds an additional and related distinction: The more abstract and psychologically distant a medium is, the more uncertain it is, and the greater is its ability to induce new ideas in the design process, or in other words: the greater its creative potential. An interesting characteristic of designers is that they can interpret an abstract representation *as if* it is a concrete representation, and vice versa (Goldschmidt 1991; Tversky 2011). This ability to shift between the abstract and concrete stimulates discovery and creativity. Shifting occurs both *within* modes or representations, like in freehand sketching (Goldschmidt 1991), and between modes or representations, like between texts and images (Goldschmidt and Sever 2011). From the perspective of complexity theory, sketches are complex due to their ability to interact with the designer's mind: they are *metastable* representations (Kelso, Stolk and Portugali, Chap. 3, this volume).

12.5.3 Complexity, CLT and the Design Process

In Sect. 12.2, we defined the SIRN design process as a complex system that evolves by means of interaction between internal and external representations, which mediate *within* and *between* the different SIRN-submodels. Our focus of interest in the present paper is external representations in the process, namely the design medium (e.g. a sketch) and the design object (e.g. a neighborhood), both of which are artefacts. This reiterates the dilemma with which this book opens, but with respect to SIRN design: what makes the SIRN design process (that evolves by interplay between the artefacts design medium and design object) a complex system? Our answer is that, similarly to the city and other such large-scale artefacts, SIRN design is a hybrid complex system. When designing a small-scale "simple artefact", the process is a hybrid complex system by virtue of the designer as a complex system. When designing a large-scale complex artefact such as a city, the process is doubly hybrid complex system due to both the properties of the designer and of the design object as complex systems.

12.6 An Example from Urban Design: Palmbout Urban Landscapes Cross-Scale Design Instruments

In this section, we present instruments of urban design that use various scales and levels of abstraction, taken from the design process of Palmbout Urban Landscapes (Palmboom 2010), a medium-sized urban design office in the Netherlands. The Palmbout approach emerged through urban design practice and illustrates how they deal with the open-complex nature of large-scale urban design projects. This approach is a mixture of design-instruments that act on different levels that are represented by different types of drawings, involve different types of stakeholders and imply different levels of openness and control. These instruments are: framework, printed circuit, building envelope and idiom (see Fig. 12.7).

1. The *framework* deals with stable infrastructures and networks, including water and traffic systems, connections with the surroundings and position within the region. Bird's-eye-view drawings capture the essential elements of the framework and take three-dimensional elements into account.
2. The *printed circuit* determines the bonding points of the buildings: the first half meter of the vertical elements along public spaces. According to Palmboom: "*It is like Pompeii in reverse: rather than relics of a city that has disappeared, it is the preconception of a city, which has not yet arisen.*"

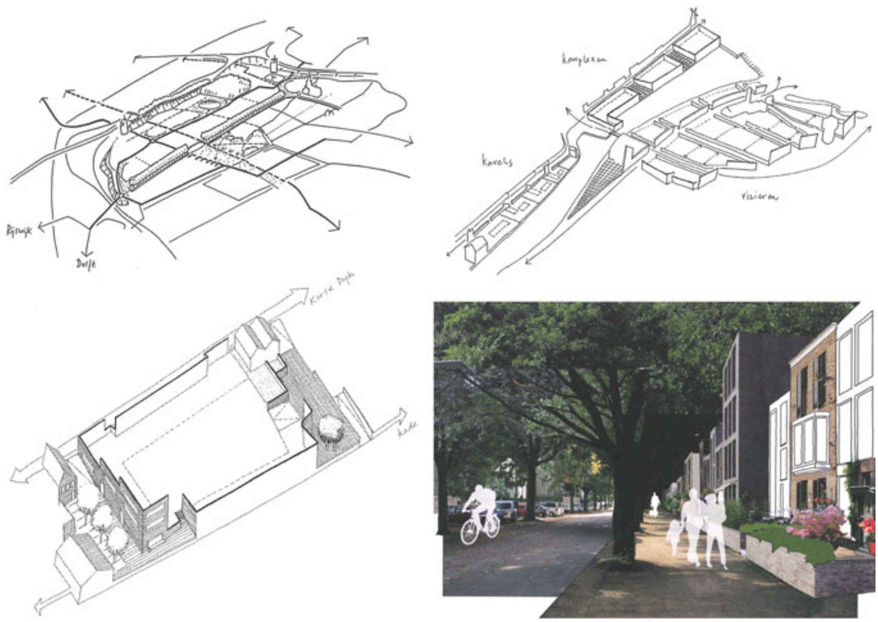

Fig. 12.7 Examples of the four instruments: [*top-left*] the framework; [*top-right*] printing circuit; [*bottom-left*] building envelope; [*bottom-right*] the idiom. *Source* Palmboom (2010)

3. The *building envelope*, borrowed from American planning practice, defines the margins within which the location can be built or intensified. On this level a variety of perspectives and cross-sections are used.
4. The *idiom* describes the prevailing tone of the architecture: the character of the plan.

In the following sub-sections we discuss the nature of these instruments in the context of this paper.

12.6.1 The Design Medium

The different instruments operate roughly at four different scales, and as such differ in their level of abstraction, resulting in different *scale-distances*. On the largest scale, the framework describes abstract connections of the area to the surroundings, *without* describing how these connections should be implemented. This is combined with essential, sometimes even concrete, elements. As such, this instrument combines several *design medium-distances*. On the smallest scale, the idiom might appear to be a concrete representation, but is actually an illustration of how a typical street *might* look. As such it describes the *abstract character* of the plan at eye-level.

The different instruments and their design medium-distances and scale-distances are shown in Fig. 12.8.

This abstract character, and its related uncertainty, gives the plan the potential to induce new ideas and enlarge its creative potential. The open character of the instruments complements this creative uncertainty and facilitates the collaborative design process.

The design instruments also serve as *boundary representations*. At a point in the process abstract notions, and their corresponding abstract external representations, are translated into more concrete plans. In most cases professional designers, such as architects, landscape architects and urban designers, do this translation. After the more concrete plans are realized, the instruments will be translated into more formal planning tools, such as zoning plans, on the basis of which other designers—including the latent designers (the city's users and inhabitants)—can take over and plan and design their part.

12.6.2 The Design Process

Although design drawings are likely to be produced by a single designer (as an intrapersonal SIRN process), the ideas that have led to these are the result of several SIRN processes. The municipality of The Hague initially developed the basic ideas for Ypenburg. In this case, the drawings are the result of a co-design process

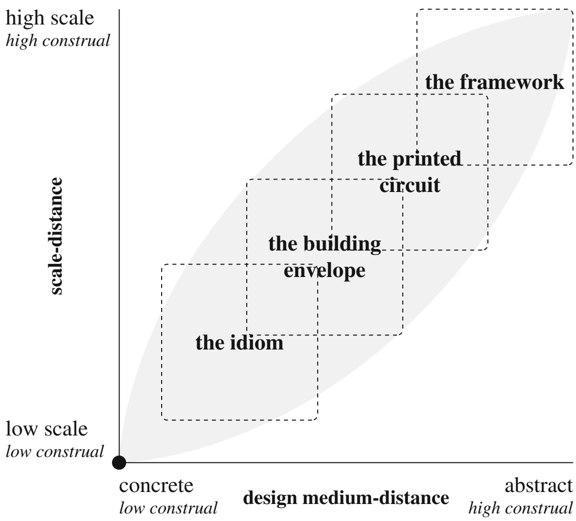

Fig. 12.8 Scale distance and design medium-distance of the different representations as used by Palmbout Urban landscapes

involving a variety of co-designers, stakeholders and other designers, resulting in a *collective SIRN process*. Next to these 'fast' SIRN processes, there's an interaction with 'slow' SIRN processes: the long timespan of implementing the plan tends to result in minor or major adjustments caused by changes in the context during the implementation.[6] In this case both the designer and the design object are complex systems, resulting in a hybrid complex system.

12.7 Concluding Remarks

The complexity-cognitive, or SIRN-CLT, view on scale in urban design presented in this paper sheds new light on the relations between the scales of design objects, the design medium and the design process. We show that these relations are based on a distinction between small-scale and simple design objects versus hybrid large-scale and complex design objects, as well as on a distinction between 'fast' and 'slow' SIRN processes. In line with these distinctions, we further propose two novel CLT-dimensions: scale distance and design-medium distance. The SIRN-CLT view on scale in urban design, outlined in this chapter, is a first sketch that opens up possible future research into the proposed CLT-dimensions, their interrelations and their relations with other dimensions of psychological distance.

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[6]As described by Kelso, Stolk and Portugali (Chap. 3, this volume), these processes interact, and are complementary in nature.

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Chapter 13
Lines: Orderly and Messy

Barbara Tversky

Abstract People arrange things in the world. Those organizations, dishes of various sizes and shapes piled up on shelves, windows aligned on buildings, buildings lined up on streets, create regular patterns, patterns that contrast with the random patterns of nature. The patterns are good gestalts that the eye sees, vertical lines, horizontal lines. The boxes they create form tables whose entries contain and may order like kinds. The lines and arrangements can support abstract ideas, categories and hierarchies, repetitions and symmetries, one-to-one correspondences and orderings, embeddings and recursions. Designing architectured spaces also relies on lines, not the orderly lines in the visible world, but vague messy ones. The ambiguity of these configurations of lines allows many interpretations, fostering the flexibility and creativity essential for design. Lines are what the hands draw, what the eyes see, and what diagrams the world.

13.1 Introduction

A number of years ago, in a talk to an interdisciplinary audience at Columbia, the architect Schlossberg (2009) made what was to me a startling claim: Architecture is information. No, I thought naively, architecture is concrete: it is bricks and mortar. Information is abstract, in the mind or in the cloud. Architecture is the buildings that give shelter, the bridges that allow passage, the gardens that provide pleasure; some we admire for their elegance and beauty, some we decry. But the claim stayed with me, there must be a way it could be true. And here's how: construction is the bricks and mortar, and architecture is design. Architecture is in the mind, and expressed on paper, actual or digital, or in models or words or gestures. Architecture is

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sometimes, but by no means always, and by no means necessarily, expressed in the world. Architecture informs.

Architecture informs in simple, direct ways. The human-sized vertical rectangle anchored to the ground that we call a door offers access. The smaller transparent rectangles layered on the walls and not anchored to the ground that we call windows allow light, air, and visibility. The long narrow rectangles bordered by walls along the floor that we call corridors allow passage. Perception of these kinds of structures invite specific actions, direct perception-action couplings that Gibson called *affordances* (Gibson 1979). Fundamentally, architecture informs the structure of the designed object, and the structure, in turn, guides behavior. Where to enter, where to find stairs or elevators, which corridors lead somewhere, which are dead-ends. Architectural style informs: this is a courthouse, this is a church, this is a discount store, this is an expensive neighborhood, this is one in transition. These ideas are not new, they are at the heart of the practice. Architecture can do these things subtly or blatantly, elegantly or crudely.

But architecture can inform much more than style or function. Now it is my turn to make claims about architecture, design, and information, different claims, perhaps more startling than Schlossberg's: Architecture diagrams the world. Next: Architecture communicates abstractions. Here I am referring to visible tangible architecture, architecture as expressed in the world. By contrast, consider the undesigned world, the scattered leaves in Fig. 13.1. These are an example of what the world looks like as created by nature, not by design.

Not perfectly random, but certainly helter-skelter. Now compare that to what the world looks like as created by design, here the regular city-block pattern of midtown Manhattan in Fig. 13.2.

Fig. 13.1 Scattered leaves

Fig. 13.2 Midtown Manhattan. Quite different

13.2 Orderly Lines

The architectured world is not random, it is orderly. The architectured world is not helter-skelter, it is patterned. Locally, the world does appear flat, and the flatness of the earth provides a seemingly endless line, that of the horizon. The architectured world is built on that, and built against gravity, a ubiquitous force that shapes everything in the world. Stability in the world requires lines that are parallel with the horizon and perpendicular to it, parallel with gravity, joined by right angles. Things oriented horizontally and vertically stay put, both natural things like trees and constructed things like buildings. Diagonal things, even slightly tilted things are unstable, like the many leaning medieval towers in Italy. The antithesis of lines at right angles: round. Round wheels readily roll, exactly because they are unstable. Perhaps that is one reason wheels took so long to invent.

The natural world, animal, plant, or mineral, also cannot escape the constraints of the ground and of gravity, and those create their own patterns. Notable among them are crystal lattices in minerals and bilateral symmetry in plants and animals, both revealing the forces that created them. But horizontal and vertical lines and the rows and columns and boxes formed by them, do not appear frequently in nature; rather, they are characteristic of the designed world.

The architectured world is created by purposeful actions and designed for purposeful actions. Inside buildings, there are the lines formed by the shelves used to organize books, the lines formed by the cabinets that organize linens and dishes, the lines formed by bureaus that organize clothing, the walls and doors that separate rooms that have different functions and therefore contain different kinds of things. These lines encompass concepts. There are the lines of the corridors that connect rooms and office. Outside, there are the lines formed by the streets along which houses, stores, and parks are arrayed. There are the lines on the sidewalks and the lines on the streets, those separating lanes of traffic, those at cross-walks. The lines of bridges crossing rivers. Some of the lines are dotted, connected by the eye: the horizontal and vertical lines aligning windows on high-rises, the lines linking seats in auditoria, the lines connecting desks in classrooms. The lines can separate, as in boundaries. The lines can connect, as in paths. The lines can outline shapes. The perpendicular and parallel lines create patterns. The patterns repeat. They form good gestalts and catch the eye. They intrigue. Because they were likely to have been intentionally created by sentient minds, they invite discovery of those intentions.

Of course the lines of architectural design are not always straight, nor the angles always 90°. Rows of seats in auditoria are often curved, as are mountain roads. There are the domes of the Pantheon in Rome and Brunelleschi's Duomo in Florence. There are the sculptural creations of Gehry and Haddad. Sometimes the lines come back on themselves, creating circles, as in traffic circles or round tables and the chairs surrounding them But these are still lines, and the departures from parallel and perpendicular have orderly reasons, curved rows provide broader visibility of the stage, curved pathways create slower, more relaxed exploration with more views. The curved lines, just like the straight ones, reveal, indeed, *diagram,* the organization of the chairs and the houses. And by diagramming the organizations imposed on the spaces, they diagram the concepts underlying the organizations. This is a much deeper sense of the claim that architecture is information.

These patterns are not the same as the architectural patterns analyzed by Alexander and colleagues in their landmark book, *Pattern Language* (1977). Their patterns were ideals, arrangements of entities to solve problems; how to arrange a bedroom, a coffee shop, a town, small or large. Their patterns were plans, partly prescriptive, partly descriptive, that could be instantiated in myriad ways yielding quite different appearances. Here the analysis is of appearances, the tangible visible patterns encountered in the world. The focus is on what those visible patterns represent and how they do it.

The designed world diagrams itself through its lines. The diagrams reveal the conceptual organization of the world. One fundamental way that people organize their minds and their world is by categories of like things. People group like things together and separate them from different things. In the kitchen that organization is evident in drawers and on shelves as in Fig. 13.3.

Notice that the dishes are lined up horizontally on shelves that have vertical borders. The shelves and the borders form boxes, a matrix or a table. For the most part, the shelves separate different kinds of things and contain the same kinds of things; here, plates on one shelf, bowls on another, cups on a third. Within each box

Fig. 13.3 Kitchen cupboards with hierarchical organization of dishes

are vertical piles that are sub-kinds. In the lower box, there are small plates and large ones; in the second box, piles of bowls of three sizes. The kinds and sub-kinds are grouped by form and use, which coincide. (Now is a good time to note the design of the dishes; they are meant to be stacked in like piles). The orderly boxes formed by the horizontal and vertical lines and the orderly vertical piles signal abstract information, specifically, categories, and categories and sub-categories, hierarchical organization. The architectural design provides the structure: the vertical and horizontal lines signal hierarchical organization. This pattern and this organization are to be found everywhere in the designed world. Different categories and hierarchies of categories are apparent in other rooms of a house: linens, toys, clothing, and more. And in the shelves of all kinds of stores, like those in this 24-hour store in Tokyo, seen in Fig. 13.4.

Fig. 13.4 Display of snacks for sale in a Japanese 24-hours store showing hierarchical arrangement of goods

The architectured world displays and diagrams other kinds of abstractions through the regular arrangements of objects. Think of a typical table setting as in Fig. 13.5.

Fig. 13.5 Table setting showing one-to-one correspondences

Fig. 13.6 Facades of buildings in Piazza delle' Erbe, Padua, Italy

Unlike the kitchen cabinets, the plates and bowls and cups in a table setting are not arranged in piles by kind. Rather, they are distributed so that each diner gets one of each. Here we have one-to-one correspondences, a concept crucial to counting, arithmetic, mathematics, logic. And business. One-to-one correspondences are common in larger scales as well, often in the harmonious facades of buildings, as those in Piazza delle' Erbe in Padua in Fig. 13.6.

One-to-one correspondences abound in both buildings, on the left, the market, the 15th c. Loggia della Gran Guardia, and on the right, the white 16th c. Palazzo del Capitano. Symmetries and repetitions also abound. Here, the patterns expressing the abstractions are neatly delineated by columns and rows. The identical windows and balconies and porticos arrayed in the rows suggest the presence of internal boxes with similar features and purposes within each row. The rows differ, but are neatly aligned with the columns, suggesting internal differences that coordinate with the columns. Symmetry and repetition are concepts fundamental to art, to science, to mathematics, and of course to architecture and design. Recursion and embedding are also concepts fundamental to abstract thought that are evident in building facades and elsewhere. These abstract ideas can be inferred from the patterns people create in the world.

In many cases, things are not only placed in bins but also lined up in deliberate order, books, for example, by size or alphabet or date. In assembly lines such as the one in Fig. 13.7, the spatial order represents a temporal order as well as a spatial one.

Fig. 13.7 A Ford assembly line in1913. Public domain. Courtesy of Wikipedia: http://commons.wikimedia.org/wiki/File:Ford_assembly_line_-_1913.jpg

Altogether, the range of abstract concepts that design captures and conveys is impressive. We have noted examples of categories, hierarchies of categories, one-to-one correspondences, symmetries, repetitions, embeddings, recursions, and ordinal relations. The linearity and regularity of the patterns make it likely that they were intentional creations and invite investigation into those intentions. These spatial organizations represent abstractions, and those abstractions can teach a deeper understanding of the world.

The diagrams created by designing the world can teach by calling attention to themselves and inspiring inquiry into their meanings. On the one hand, they can teach the specific content, that dishes, clothing, food, rooms, and so on come in categories and subcategories, that cars are manufactured part by part in a meaningful order. That the categories and orders and correspondences and symmetries are characterized by specific features, for example, kinds of dishes and clothing by size, shape, and function. The diagrams can also teach abstractions, that things in the world belong to categories and subcategories, that they can be distributed one-to-one, that the patterns of things can be ordered and repeated and embedded, wholly or by parts. The diagrams in the world can allow people, even very little ones, to make inferences from structure to content and from structure to kinds of structures. That way, the intelligence of the designed world can increase our own.

13.3 Messy Lines

Now let's turn from the neat and tidy designed world to the act of designing. Consider one sketch from one architect's design of a museum (Fig. 13.8).

The organized rectified world is nowhere to be seen in this sketch, nor for that matter is the design. Instead, there are lines, lines that are tentative, messy, vague, uncertain. At this point, the sketch, which represents the beginnings of a design of a museum by an experienced architect (Suwa and Tversky 1996), looks more like the scattered leaves in Fig. 13.1 than the modern or Renaissance buildings in Figs. 13.2 and 13.6. The lines are not easy to interpret; are they roads or buildings or contours of the ground? The lines are ambiguous; that is, they are consistent with myriad interpretations. And that is the point. The very ambiguity of the sketch allows multiple interpretations and reinterpretations. Rather than freezing a design into a final form, the sketchiness of the drawing encourages considering many alternatives. Architects and designers rely on the tentativeness of sketches to formulate

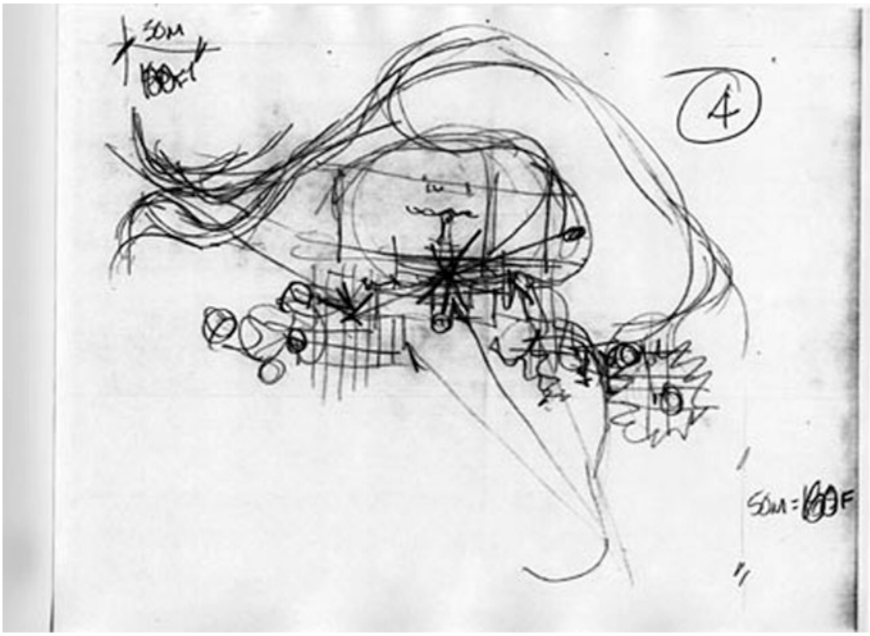


Fig. 13.8 An architect's early sketch of a museum design (Suwa and Tversky 1996)

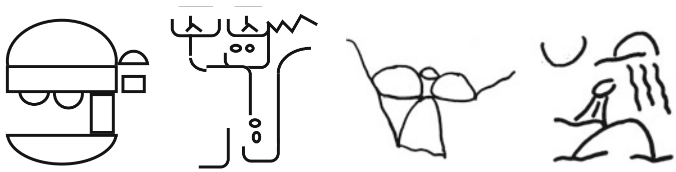
their ideas (e.g. Goldschmidt 1994; Schon 1983). So do artists, as they develop their drawings (e.g., Kantrowitz 2014) and so do scientists as they search ambiguous data for explanations (e.g., Keim 2001; Levinson and Kaplan 2013). Ambiguity, notably in sketches and diagrams, allows exploration of ideas and discovery of new ones.

How do people make new discoveries in ambiguous sketches? As many have noted, like so many perceptual and cognitive processes, thought and discovery are typically interactions between what is in the mind and what is in the world (e.g., Bjorndahl et al. 2014; Hutchins 1995; Kirsh 1995; Portugali and Stolk 2014; Tversky 2011; Tversky and Kessell, in press). In fact, a critical challenge for any specific design situation is one of meta-design: the design of the cognitive tools for thinking and discovery.

To learn more about the interplay between minds and cognitive tools, in this case, sketching, we video-taped experienced and novice architects as they designed a museum given certain constraints (Suwa and Tversky 1996). Afterwards, we went through the video with them, asking them why they drew every line that they drew, video-taping these sessions as well, and then analyzing those recorded protocols. Both novice and experienced architects reported making numerous discoveries in their own sketches, seeing aspects of the design that they had not intended at the time that they sketched. The new discoveries were productive: that is, they led to new design ideas (Suwa and Tversky 1996; Suwa et al. 2001). Although both novice and experienced architects made new discoveries in their own sketches, the novices made mostly perceptual discoveries whereas the experienced architects made functional as well as perceptual discoveries. Novice architects, like experienced ones, made primarily perceptual discoveries about size, shape, distance, and pattern, that is, about features that were visible in the sketches. However, experienced architects not only made perceptual discoveries but also made more conceptual discoveries than novices from their sketches, that is about features that were not visible in the sketches but rather inferences from those features, such as how the traffic would flow or how the light would change during the day and with the seasons. Experienced architects were able to infer the consequences and implications of their designs, consequences that were not directly depicted.

How did the architects, especially the experienced ones, make new discoveries? They reported that they made discoveries in their sketches when they regrouped the elements of the sketches in their minds, when they mentally reorganized their sketches. Think of Necker cubes. Ambiguity fosters reorganization and regrouping.

To explore those processes in detail, we brought a model of the task into the laboratory, adapting procedures developed by Howard-Jones (1998). In a variety of studies, we asked people, some designers, some ordinary people, to come up with new interpretations of the ambiguous sketches in Fig. 13.9, presented repeatedly one at a time (e.g., Suwa and Tversky 2001; Suwa and Tversky 2003; Tversky and Chou 2010, forthcoming; Tversky and Suwa 2009). On each trial participants were provided with a sketch and asked to produce a new interpretation until they ran out of ideas.



Drawing 1 Drawing 2 Drawing 3 Drawing 4

Fig. 13.9 Sketches given to participants for repeatedly generating interpretations

We found that expertise, skills, and task variables all affect the fluidity of new interpretations. Experienced designers get more ideas from ambiguous sketches than novices. Experienced designers are also more resistance to fixation, they keep getting new ideas when novices have stopped. Thus, expertise matters, but so do abilities, both perceptual and conceptual. Designers (and scientists) need both: they need the bottom-up perceptual skills required to reconfigure the givens, sketch or data, and they need the top-down conceptual skills required to think broadly in order to connect the configurations and reconfigurations to interpretations. We assessed each of those skills in one study (Suwa and Tversky 2003), using psychometric indices of each. The perceptual skill was assessed using the Embedded Figures task (Gottschaldt 1926). On each trial, participants were given a small simple figure and asked if that figure were hidden in a large complex drawing. We chose this task because architects in the earlier study reported that getting new ideas from sketches depended on mentally decomposing and reconfiguring them. The conceptual skill was assessed using the Remote Associates Test (Mednick and Mednick 1967). On each trial, participants were given three words, such as *thread, pine*, and *pain*, and asked to find another word relating them, in this case, *needle*. Interestingly, the two skills were independent; that is, there was no correlation between the scores on each. Each skill, however, correlated independently with the number of new interpretations, so that individuals who were adept both at Embedded Figures and at Remote Associates produced the highest number of new interpretations.

Fluidity in finding new interpretations depends on both perceptual reorganization and on divergent thinking. These skills work together through a process we called *constructive perception* (Suwa and Tversky 2003). Constructive perception means actively using perception in the service of some end, in this case, finding new meanings, new interpretations. Because constructive perception entails decomposing and recomposing parts and wholes, arranging and rearranging them, finding new relationships, taking new perspectives, and connecting those to interpretations, functions, or goals, constructive perception should be a general skill set or mind set for innovative thinking, not just for design of tangible objects and buildings but for design in any domain.

Certain arrangements of the tasks encourage finding new interpretations of ambiguous figures. Rhythm matters. Interleaving the different sketches in a random order yielded more new interpretations than presenting identical ones in blocks

(Tversky and Chou 2010). The advantage of spaced presentation of the figures is probably both perceptual and conceptual. Perceptually, it should be easier to take a new perspective on a sketch when it hasn't been viewed for a while, especially when the sketch is ambiguous. Conceptually, it should be easier to think of new interpretations when a sketch hasn't been viewed for a while. Interestingly, each figure induced its own domain of interpretations; there were almost no cases of transferring a domain of interpretation from one figure to another. Thus, the figures weren't completely ambiguous, they did suggest some domains and some examples within the domains more than others. For example, Drawing 1 yielded many kitchen appliances and Drawing 4 yielded seashore scenes. However, a completely ambiguous sketch, a dot or a line or no mark at all, would probably yield very few interpretations. Perhaps we have a Goldilocks effect: to be fruitful, sketches must be just right, not too hot and not too cold, not entirely certain and not entirely ambiguous.

Mindset seems to make a difference as well, and can be induced. New groups of participants were presented with the sketches in random order and asked to find a new interpretation each time they saw a sketch, as in the previous studies. Some participants were given mindsets for finding new interpretations, either a perceptual mindset or a conceptual mindset or both. The perceptual mindset suggested that mentally regrouping the elements would encourage new interpretations. The conceptual mindset suggested that thinking of new domains of objects or scenes would encourage new interpretations. The two mindsets, then, correspond to the two components of constructive perception. The effects of the mindsets were intriguing (Tversky and Chou, forthcoming). As noted, people tended to give groups of related interpretations, that is, interpretations from the same domain. Drawing 1 tended to elicit the domain of kitchen appliances, with a varying number of ideas, and drawing 4 tended to elicit the domain of beach scenes, with a varying number of ideas. We counted both the total number of different ideas, whether or not they were in the same domain, and the number of different domains, irrespective of the number of ideas produced for each. For sheer number of ideas, having a mindset produced more ideas than not having a mindset. Furthermore, the conceptual mindset was superior. For number of domains, either mindset elicited far more domains than no mindset. However, having both perceptual and conceptual mindsets was no better than no mindset. This is probably because trying to use both hints was like trying to use everything, the default case for those not provided with a mindset. Together, the results suggest that hints serve to focus thought by giving thinkers a principled way to search for and construct new ideas. There was some evidence that a top-down conceptual strategy is more effective than a bottom-up perceptual strategy, perhaps because the conceptual strategy provides better ways to search and better ways to generate interpretations of figures that allow many interpretations.

Ambiguity doesn't necessarily coincide with messy lines. Giacometti's drawings come to mind; out of a jungle of line stubs seemingly going anywhere emerges a beautifully articulated face and body. Picasso's paintings of his mistresses illustrate the opposite; from clear clean lines drawn from several simultaneous perspectives emerge incoherent unstable images of faces. Both attract the eye, in the case of Giacometti, to discern the single intended image, in the case of Picasso, to consider a multitude.

13.4 Lines on the Page, Lines in the Brain, Lines in the World

Lines are what the hand draws and what the eye sees, a magical convergence. The world the retina captures is unformed sparkles of light of varying brightness and hue. The brain connects the dots (Hubel and Wiesel 1968; Marr and Hildreth 1980). Connected, dots form lines, lines that are straight that form horizons or paths or platforms or edges, lines that bend or curve or twist around that define figures, objects, buildings. Architects draw lines to design, first messy tentative lines that can be interpreted and reinterpreted, but ultimately clear forceful lines, lines that guide construction, lines that when instantiated in the world will organize the things in the world, lines that will form patterns that will intrigue our eyes, line that will create diagrams that will reveal how the world is organized and how to behave in it.

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Chapter 14
Creative Challenge and Cognitive Constraint: Students' Use of *A Pattern Language* for Complex Design

Stephen Marshall

Abstract In *A City is Not a Tree*, Christopher Alexander identified the creative challenge of how to generate the intricate complexity of traditional urbanism. In doing so, he also hypothesized a cognitive constraint: that it is too difficult for planners to conceive the kind of complexity found in traditional urban structures in a single mental act. To explore the relationship between complex design, creative challenge and cognitive constraint, this chapter reports on student design exercises using Alexander's *Pattern Language* as a generator of urban form. The study provides insights into the creative challenge faced by students using patterns in their designs, and helps shed light on the cognitive aspect of design using patterns; and hence draws conclusions about the implications of using patterns for creating complex designs.

14.1 Introduction

In his classic essay *A City is Not a Tree*, Christopher Alexander identified a creative challenge facing urban designers and planners: that of how to generate the intricate complexity of traditional urban structures, instead of the more simplistic, dysfunctional structures of Modernist planning (1965). In doing so, Alexander also identified a cognitive constraint to planning complex urban environments: in short, he hypothesized that it is too difficult for planners to conceive the kind of complexity found in traditional urban structures in a single mental act. This constraint called into question whether it was possible to plan towns—in the sense of consciously recreating the complex functionality of successful urbanism. Alexander's point remains significant to the extent it remains unresolved to this day.

The creative challenge—how to design functional complexity—remains despite the fact that urban designers and planners increasingly appreciate the almost organic

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complexity of cities and recognize the potential for bottom-up urbanism (Batty 2005; Portugali et al. 2012). But when it comes to professional designing and planning, these still tend toward preconceived solutions in which the complexity is mechanistically imposed, artistically contrived or superficial. A telling contemporary example is the neo-traditional set-piece that is Poundbury, where the irregularity of the layouts are precisely contrived prior to construction, as 'top-down' as a traditional Modernist master plan (Marshall 2009).References Batty (2005), Lynch (1960) are cited in the text but not provided in the reference list. Please provide the respective references in the list or delete these citations.M. Batty, Cities and Complexity. Understanding Cities with Cellular Automata, Agent-based Models, and Fractals. (MIT Press, Cambridge, Mass., 2005) K. Lynch, The Image of the City (MIT Press, Cambridge, Mass:, 1960).

That said, Alexander himself has continued to draw a clear distinction between 'designing' buildings or urban places, and 'making' them through other means. One could interpret Alexander's career since *A City is Not a Tree* as his own attempt to answer the challenge of generating viable complexity (Mehaffy 2007, 2008), through *The Timeless Way of Building* (Alexander 1979) and *A Pattern Language* (Alexander et al. 1977), and subsequently in the *New Theory of Urban Design* (Alexander et al. 1987) and *The Nature of Order* (Alexander 2002–2005). In particular, *A Pattern Language* addresses ways of generating the interlocking, overlapping urban fabric that Alexander desires to recreate, and that Modernist planning failed to equal in its more simplistic quest for functional urbanism. Scrutiny of how designers use *A Pattern Language* today could help us understand the challenges of designing for complexity.

But this is not all. The fact that the creative challenge seems to remain unresolved raises the question of whether the difficulty in creating viable functional complex designs is due to the cognitive constraint originally suggested by Alexander, or to something else entirely. Alexander's hypothesis about the cognitive constraint remains untested (Marshall 2012). This in turn raises the question of the extent to which complex design is viable (where 'design' is understood as the traditional 'designerly' way of generating form that is both complex and functional, as opposed to urban creation by more spontaneous forms of generation), and hence questions the possible limits of urban design and planning.

To explore the relationship between complex design, creative challenge and cognitive constraint, this chapter reports on student design exercises using *A Pattern Language* as a generator of urban form. The study provides insights into the creative challenge faced by students using patterns in their designs, and helps shed light on the cognitive aspect of design using patterns. The chapter begins by reporting on the interlocking, overlapping nature of Alexander-style patterns. It goes on to describe the student exercises, analyzing the students' experience of the creative challenge and cognitive constraints, then draws conclusions about the implications of using patterns for creating complex designs.

14.2 Patterns: Morphology, Modularity and Design

In *A Pattern Language*, Alexander and his co-authors (1977) set out a system of 253 patterns, each of which provides a solution to an urban problem. These include familiar morphological phenomena such as concentric DENSITY RINGS, proffered as a target future form, and wider innovations such as NETWORKS OF LEARNING. It also includes abstract concepts such as PUBLIC-PRIVATE GRADIENT as well as physically-specific suggestions, such as the dimensions of SMALL PUBLIC SQUARES. Each pattern is not a stand-alone element but explicitly supports or is supported by other patterns, creating a complex, interwoven system of urbanism.

The system of patterns is seamless across scales (from regions to construction details) and across disciplines (planning, urban design, architecture, interior design and engineering). Of course, any system of design or morphology could recognize ‘things at different scales.’ What is distinctive about *A Pattern Language* is the way these are explicitly interpreted as interlocking and overlapping (Marshall 2011). It is not just a matter of identifying morphological units such as streets, blocks, plots and buildings all neatly nested within each other—although this is a convenient way of dividing up the urban fabric and abstracting topological relations (Conzen 1960; Habraken 1998; Marshall 2009, 2015; Kropf 2014). Nor is it simply that units of design *should* be hierarchically arranged—for example with the engineer laying out a superstructure of main roads, the planner laying out discrete land parcels in between, and the architect then dealing with the design within individual plots. Or, to use a more recent example, software such as City Engine creates morphologies based on a hierarchical nesting of streets, plots and building footprints (e.g. Parish and Müller 2001).

Rather than such a neat nesting of elements, the interlocking, overlapping nature of urban fabric means that, for example, a façade is simultaneously part of the design of the building and the design of the street. Building and street are locked together. One cannot design (part of) one without designing (part of) the other (Marshall 2011). This complexity has nuances of ambiguity (Kropf 2014) and (post) post-Modernism (Turner 1996) that implies that traditional processes are not so readily converted into algorithms or simple design procedures.

From a historical perspective, the complex interlock was an important aspect of the traditional urban fabric. Then Le Corbusier swept this away, in eschewing the corridor street and the courtyard block (Panerai et al. 2004); Modernist design and planning did not need to deal with these interlocking, overlapping aspects, leaving the architect free to design the buildings as they wished, and the roads to be designed separately according to their own geometry. The façade became simply part of the design of the building—no longer part of the street, because the street no longer existed. The result was the lack of a modern theory of how to design these interlocking units of street-based urbanism. That is, there was no modern (formal, professional, systematic) way to design streets, since streets (as such) were not part of the Modernist canon (Marshall 2011).

A Pattern Language helps to fill this gap. It could be argued that *A Pattern Language* is interpretable as a 'modern' approach in the sense that it is trying to make a conscious, progressive improvement on the design practice of its time. As a whole, while inspired by traditional approaches, or even (as is claimed) part of a single 'timeless way', *A Pattern Language* is a dedicated, new package of elements and tactics for creating urbanism. This new method is not a direct codification of a single set of traditional practices, not least because of its inability to resist unprecedented innovations, whether INDEPENDENT REGIONS or systems of one way PARALLEL ROADS. As such, *A Pattern Language* can be interpreted as a self-consciously idealistic new artificial language—a sort of urban morphological 'Esperanto'—cobbled together from knowledge of existing linguistic traditions.

Although Alexander's work is typically associated with gradualism—slow, incremental processes of design building on prior traditions—*A Pattern Language* arguably supplies an *accelerated* way of generating the kind of complexity found in traditional urban fabrics. In other words, use of *A Pattern Language* bypasses the actual (long-lost, laborious, non-linear, incremental) processes that created the 'traditional' (surviving accumulations of) urban fabric, whatever those were; it supplies instead a mechanism for creating a new, traditional-style fabric from scratch—in a way that is not as simplistic as simply 'cutting and pasting' a traditional tissue and replicating *en masse* on a new site.

Finally, *A Pattern Language* provides a way of interpreting complex morphology and turning it into complex urban design. In this process, the medium of morphology and that of design can be regarded as equivalent (Marshall and Caliskan 2011), hence patterns can be both interpreted in existing fabrics (even if never used as building blocks for design) and used as building blocks for design (even if these were never found in existing fabrics). For example, concentric DENSITY RINGS can be interpreted in spontaneous settlement structures which never had any strategic design or strategic control of density; in *A Pattern Language* those DENSITY RINGS become formative elements for creating new urban fabrics. Conversely, innovations such as grids of perpendicular pedestrian and vehicular streets can be proposed as building blocks for a future urban layout, even if these were never found as conscious constructs on the ground. In effect, Alexander uses patterns as the fundamental building blocks of urbanism, rather than using more conventional elements such as neighborhood units, land use zones or morphological plots—unless those are interpreted as patterns.

The issue of defining the building blocks of urbanism goes to the heart of the constructive prerogative of urban design and planning. For architecture, it seems clear enough what the elements or 'building blocks' are: physically solid things like walls, windows, doors and a roof; as well as voids such as doorways, rooms and corridors. These elements are readily identified as morphological elements not least because they are typically deliberate and discrete products of design (though there are exceptions: in a cave dwelling, some of these might be undesigned natural features).

For urbanism, however, what the building blocks for design should be is much less clear-cut. If we restrict ourselves to things that are routinely designed, such as buildings, street blocks or plats, then we would miss many things that were never planned but emerged spontaneously (such as a central business district), and that could become future building blocks for design. Neighborhoods become formalized as ‘neighborhood units’; clusters of factories become the prototype of industrial estates. It remains an open question whether it is better to use macro elements such as neighborhood units and land use zones, micro elements such as blocks, plots and buildings, or Lynchian elements such as nodes, paths, landmarks, districts and edges (Lynch 1960). Alexander’s patterns provide a whole vocabulary of elements alongside rules for putting them together as a “language.” Patterns, he reminds us, are not just “things” but embed “rules for creating those things.”

This situation also begs the question: Why do we have building-blocks in the first place? While design implies conceiving as a whole, “building blocks” imply modularity and breaking into separate parts. This modularity can serve to manipulate design into elements, both physical and mental, that can be worked on by different hands (and minds).

A Pattern Language, significantly, follows a modular format; it is amenable to being worked on by many hands; it need not involve formal planning or design. That said, an important caveat to the interpretation of modularity is that elements are incomplete of themselves but form part of an overlapping, interlocking continuum across scales (see also Salingaros 2000); a door typically implies a doorway and some sort of wall that it is associated with. A door, outside the context of a wall, would be like a word isolated from the context of a sentence.

This combination of features makes *A Pattern Language* a useful teaching device for assisting learning about how urban fabrics are put together or could be put together—quite apart from its value as a distinct planning philosophy or practical design aid.

14.3 Students’ Application of *A Pattern Language*

The author has used *A Pattern Language* as part of an undergraduate course entitled “Urban Form and Formation,” a part-lecture, part-studio course bridging urban morphology and urban design, since 2008. One of the aims of the course is for students to learn about the elements of urban form, and how these relate to the building blocks for urban design. *A Pattern Language* can be considered a useful educational tool for inviting students to observe and analyze the urban fabric as it is—interpreted in terms of patterns—and then to undertake a design exercise using patterns as building blocks. This design process is in conscious contrast to using land use zones, neighborhood units or discrete elemental morphological units (such as streets, plots or blocks) as building blocks.

The course consciously encourages experimentation. The leading premise is that students need to first learn about the basic elements of the urban fabric and how they fit together—to play with them, to compose, to experiment, to get a feel for using them—before going on to undertake more formal planning or design exercises. This implies experimenting with the familiar and useful permutations of these elements to explore what might turn out to be 'nonsensical' combinations (Mitchell 1990; Steadman 1998) against which the logic and utility of familiar solutions can be better understood.

A useful analogy here is the process of learning a new language; it can help to experiment and play with the language, compose sentences, write essays and make conversation—however trivial, anecdotal or fantastic—before settling down to create serious utilitarian prose. One has to experiment with, for example, being able to say 'the cat sat on the mat,' as opposed to 'the cat sat down on the mat' or 'the cat was sitting on the mat,' and to explore alternative permutations—even nonsensical combinations—in order to learn about the language. Playing with, for example, 'the mat sat on the cat' or 'the sat cat on the mat' can help a student understand viable combinations of vocabulary, syntax, grammar and meaning (and the different ways these can be 'wrong'). When learning a language one also benefits from the joy of play and self-expression which nevertheless has utilitarian value in encouraging mastery of the language ('The cat sat on the mouse' implies another nuance of the meaning of 'sat on'—to immobilize—which implies something different from 'the mouse sat on the cat'). In urban planning education, without this sense of exploration, a student would be expected to go straight to devising a master plan for some live site, without first learning how roads and buildings are normally organized (or could be—abnormally—organized). Although this 'in at the deep end' approach may appear expedient in practice, it would be like the equivalent of learning a new language and immediately being expected to compose a formal speech, without first having had an informal conversation.

In introducing *A Pattern Language* to the class—as a way of thinking and doing, not a 'bible' with 'all the answers'—it is always emphasized that what is important is the way that the elements and relations are structured, across different scales: their interlocking and overlapping nature, and their inter-relatedness. In a sense, a thing is not a thing except in relation to both its context (the things it contributes to), and the things it is made up of. A garage, for example, implies something with walls and a roof (otherwise it might be a carport or parking bay or something else); it is also typically associated with another building, such as a house, and a connection to the street, perhaps via a driveway. Alexander et al. point out (1977) that this same physical structure would not be called a garage in the context of a boat, emphasizing that one cannot simply design an element in isolation, but must think it through in terms of a context of other (supportive and supported) elements.

Although the course emphasizes the abstract morphological structure of *A Pattern Language*, it is made clear to the students that they are not expected to agree with all of what Alexander and his co-authors say; it is not necessary to 'buy into' the whole *Timeless Way* philosophy in order to learn from it. The course acknowledges that the patterns in the book are often outdated, and cannot necessarily be assumed to be universal; critiques of *A Pattern Language* are identified (Saunders 2002), and critical thinking encouraged. The point of using the book as a starting point is that the students are free to use the pattern language as an exemplar or template for thinking about *any* patterns or urban form elements, and to consider these in the context of the processes of urban formation.

Each year the class addressed a slightly different combination of exercises. These usually involved: (1) writing a pattern (either an existing pattern updated with new research or a case study, or a completely new pattern); (2) interpreting patterns—in clusters—on site; and (3) designing—collectively—a new piece of urban fabric using patterns.

In general, the students had no difficulty in identifying Alexandrian patterns in situ, interpreting new patterns in situ, writing new patterns and creating urban form with them. The following section presents examples of this design exercise applied to two locations in London. The first set of examples are for a neighborhood-scale design on the Greenwich Peninsula in London; the second set are a design for a courtyard-scale development in the Camden area.

The concept map interpreting Greenwich (Fig. 14.1) is built up of a number of features which may be—but need not be—recognized as 'patterns'. If one did not know this was an exercise to identify then build with patterns, one might not suspect it was. In fact, Local Shops, Public Room and Web of Green Space (Fig. 14.2) are explicitly created as patterns during the exercise, along with Building Density Gradient, which can be inferred indirectly from the schematic arrows. Curiously, not all patterns that the student group used elsewhere in the exercise—such as Web of Pedestrian Space—feature explicitly in this concept map. Conversely, all the other named features, such as 'government housing' and the 'linking bridge,' are not conceptualized as patterns as such.

On the resulting map, these patterns look as if they could be a succession of separate features. Their interlocking, overlapping nature is not explicitly apparent. To be fair to the students, *A Pattern Language* itself does not explicitly illustrate the interlocking overlapping outcomes of the patterns when assembled together (Saunders 2002).

The students were creative in attempting to capture the complexity of relations between patterns. Figure 14.2 looks less like a conventional 'land use plan' than Fig. 14.1, being more in line with a tradition of schematic concept plans that are not necessarily associated with patterns per se.

Now we turn to the second case, that of Camden Town. We began with a plan of the development (Fig. 14.3) which looks conventional plan, and would not necessarily be recognizable as a pattern language exercise out of context.

Next, the students created a series of images showing the development of the courtyard over time (Fig. 14.4). This series is accompanied by a narrative (paraphrased for simplicity to the right of each image) explaining the appearance of patterns at each stage. Finally, we see two ways of visualizing the linkages between patterns. Figure 14.5 is a graph (nodes and links) representing patterns and their relationships, superimposed on a sketch. The final image (Fig. 14.6) is an abstracted graph showing the patterns as nodes and the pattern relations as links.

From observing classes over several years, it seems that while most designs are annotated with patterns, as required, it was not always clear to what extent patterns were actually the most fundamental formative elements. In some cases, it seemed that the students could not help thinking in terms of conventional land-use plans and units. For example, if devising a new town, a group would typically start by

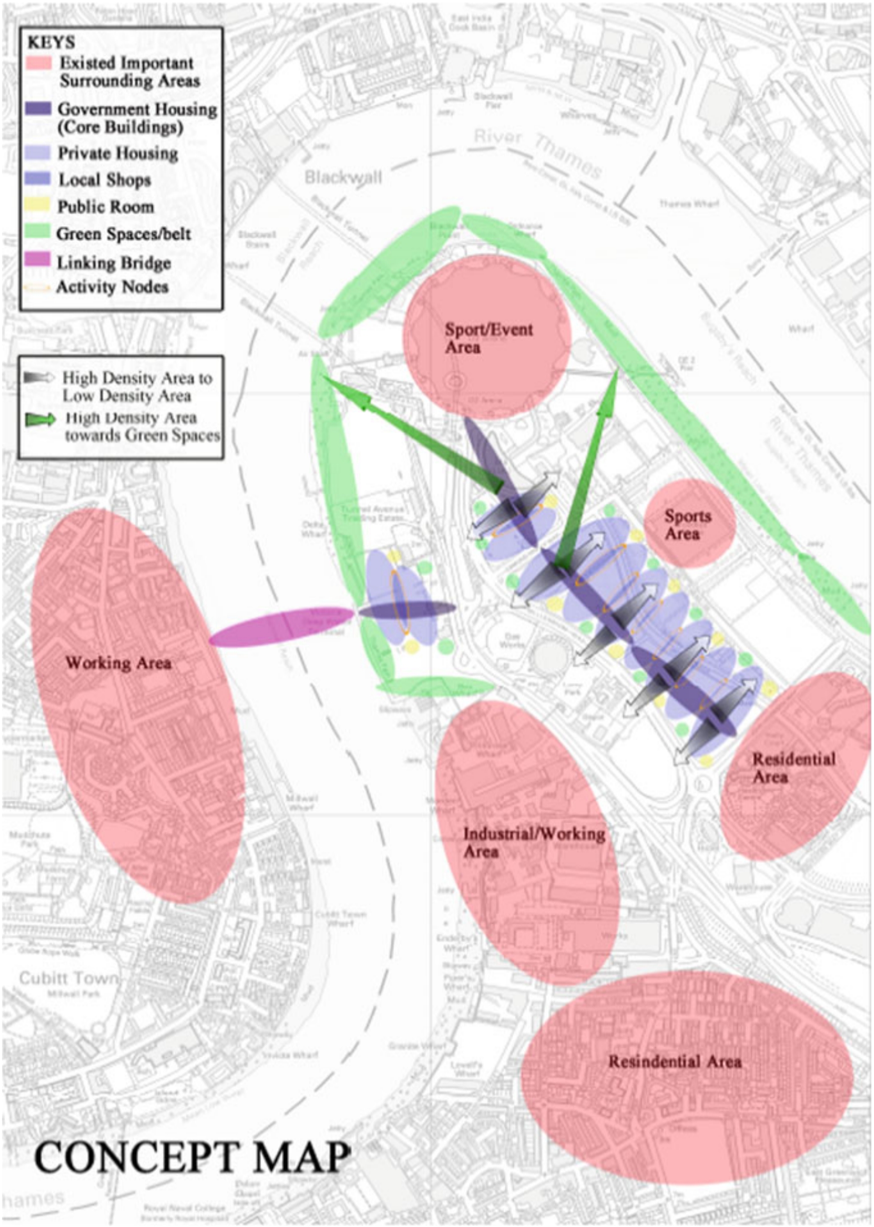

Fig. 14.1 Concept map showing the various building blocks of urban form

instinctively sketching out a town in a conventional way—with main roads, a town centre and neighborhoods or districts of various kinds—then add distinct features, such as a university campus or a public library, with no reference to patterns. After

Fig. 14.2 Sketch plan

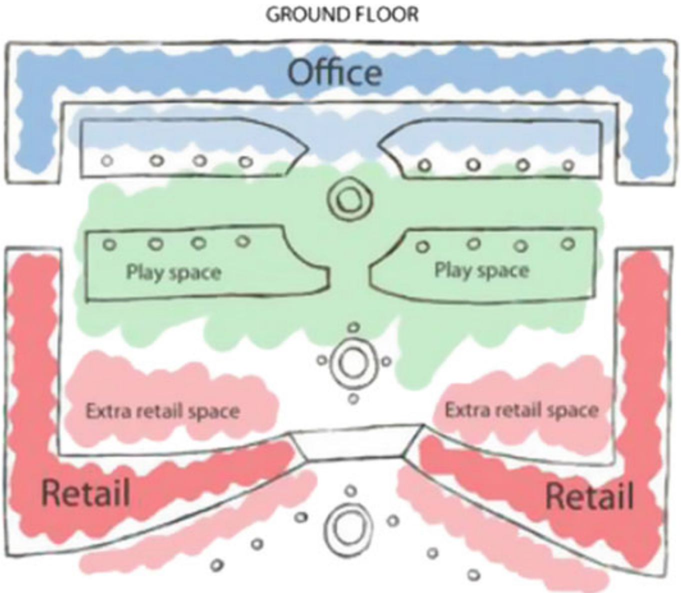

Fig. 14.3 Camden courtyard development. This could belong in a conventional master plan

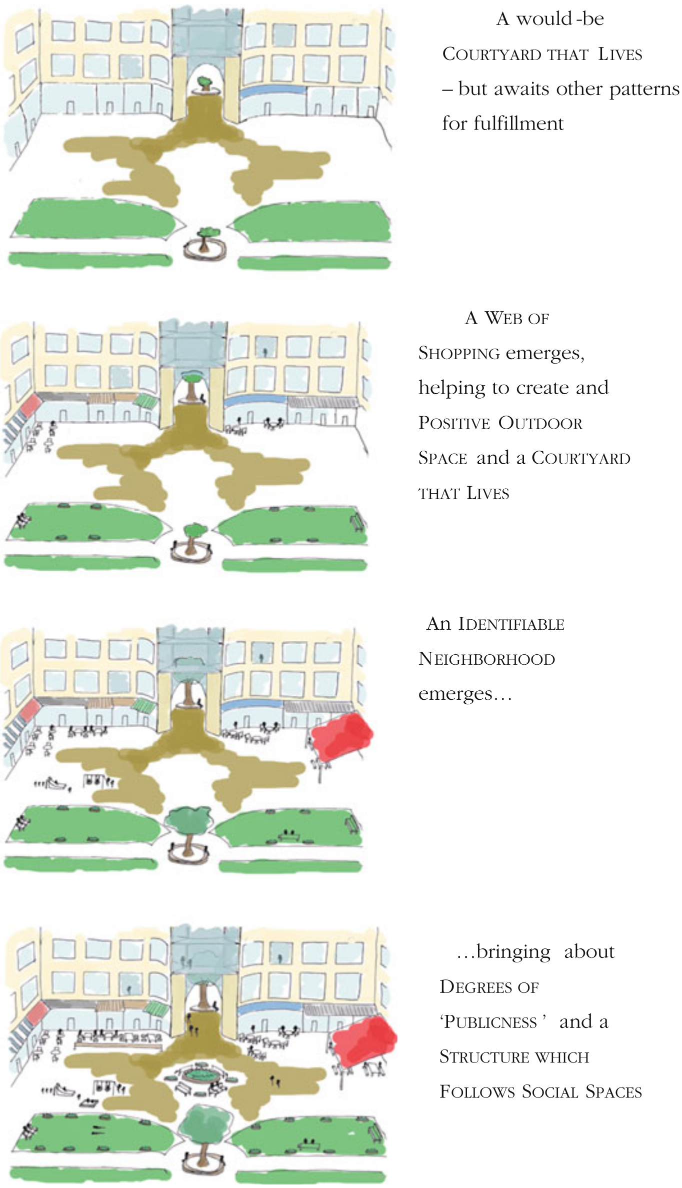

Fig. 14.4 Sequential development of the courtyard over time

the overall structure was created, the patterns might be identified as such. In these cases, it seemed that the students were not necessarily 'thinking in patterns,' but first thinking in terms of conventional building-blocks, then converting them into patterns or retrospectively labeling them as patterns. This

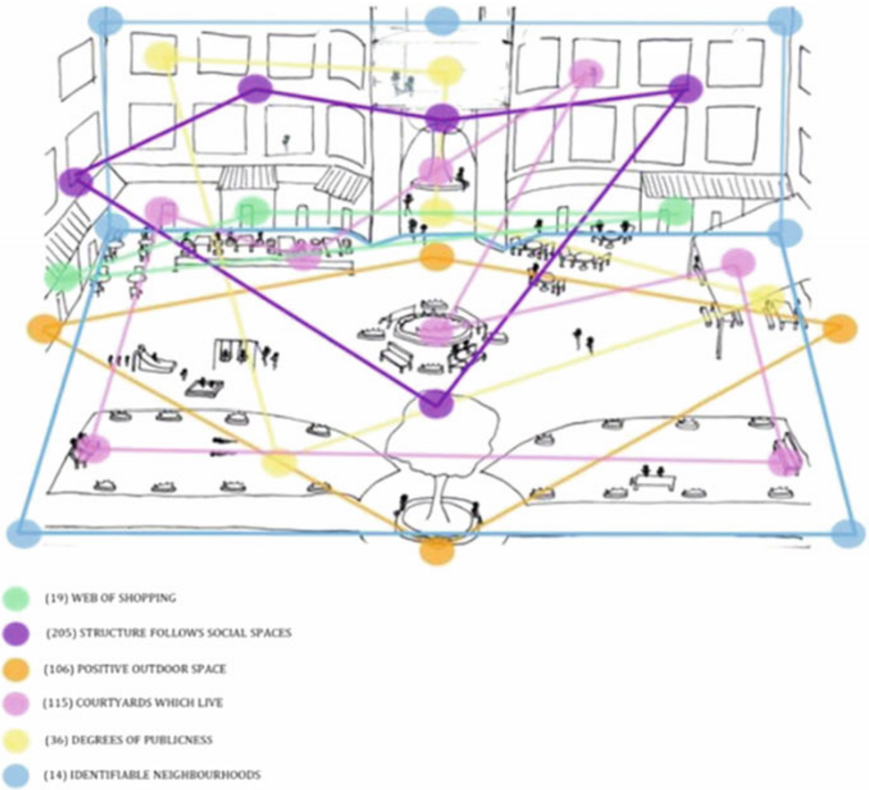

Fig. 14.5 Abstract linkages between patterns overlain on sketch

could be the equivalent of aiming to say something in a foreign language but thinking in one's native language, then translating everything into the target language; here the pattern language is the foreign language. To find out why this 'translation' process might apply to pattern languages, it seemed fruitful to ask the students to reflect on their work.

14.4 Students' Interpretations of Using *A Pattern Language*

For a recent class, students were asked individually to reflect on the strengths and weaknesses of using an Alexander-style pattern language for creating urban developments today. The process revealed attitudes to *A Pattern Language* in general, as well as the challenges of using it for complex design in particular.

From their narratives, it is evident that the students typically perceive *A Pattern Language* to be of its place and time (not so 'timeless' after all), and restricted in

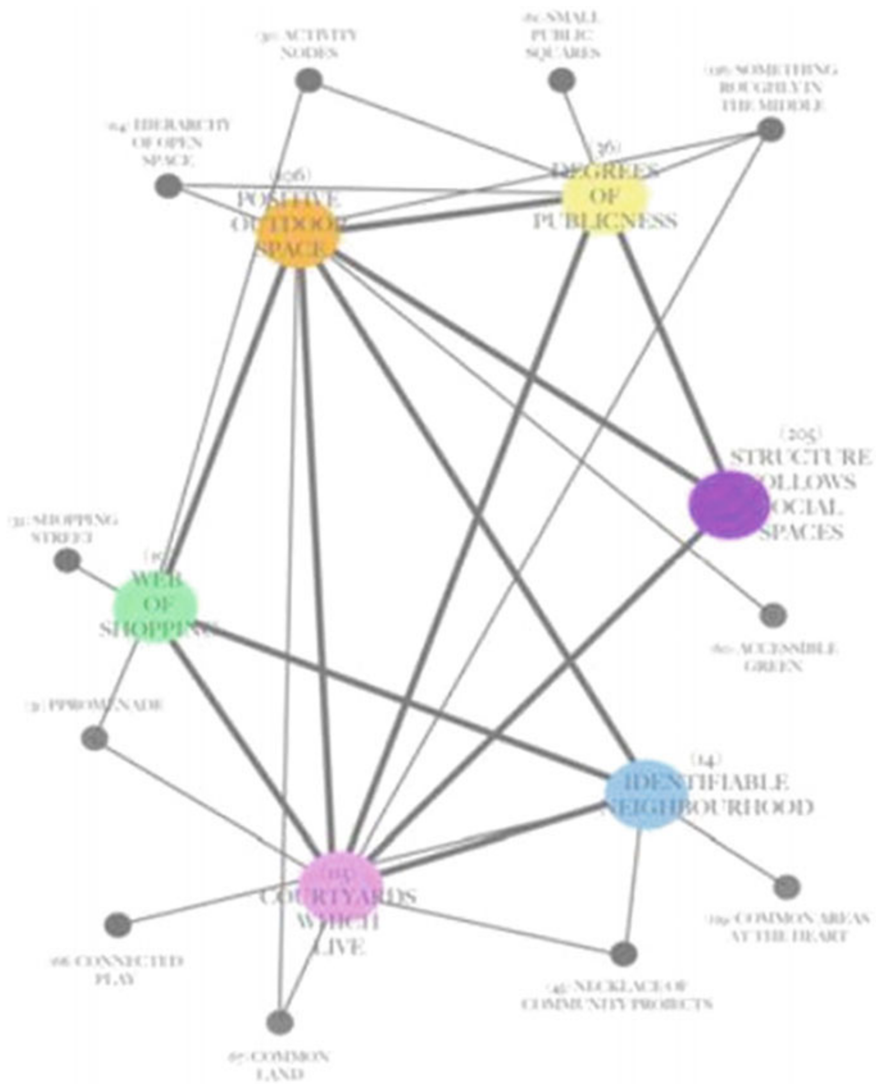

Fig. 14.6 Linkages abstracted as a graph

applicability to a western cultural context. Additionally, a typical comment was that many of the ideas in the book were unrealistic—too utopian or not reflecting actual reality. This criticism was often specifically related to how applicable some patterns would be in a market economy or the current planning context. Patterns were sometimes commended for being definite recommendations or else criticised for being too prescriptive; at other times they were commended for being flexible, or else criticized for being too vague. The potential to deal with complex forms

Table 14.1 Hypotheses about the difficulties in using *A Pattern Language*

Hypothesis	Experience
1. Patterns are not real, or difficult to identify in situ	Not borne out
2. Patterns are real in situ, but not suitable as building blocks	Compatible with student experience
3. Patterns would be suitable as building blocks, but	
(a) Students are pre-conditioned to think using other building blocks (zones, neighborhood units, etc.)	May be partly true, but not thought significant
(b) It is mentally difficult to do so (a cognitive constraint)	Compatible with student experience
(c) Less able students found it difficult	Not borne out

through patterns and to facilitate participative contributions was noted by some, as were the relative lack of attention given to actors and instruments (i.e., who would implement the patterns, and how).

Overall, the students were able to produce designs using the patterns demonstrating to some extent the viability of patterns as a way of generating urban development—at least as a paper exercise. However, as noted earlier, the students did not always 'think in patterns,' and did not necessarily use the patterns in the way intended by Alexander, but sometimes tending to use them like more conventional building blocks. There are several hypotheses as to why this might be so, laid out in Table 14.1.

In terms of the first hypothesis, it could be that patterns are figments of the authors' imaginations (Alexander et al. 1977), artificial constructs (like Esperanto) not found naturally in situ, or otherwise arbitrary or capricious interpretations of the urban fabric that have to be consciously learned, both as ways of interpreting the built environment, and for designing it.

This does not seem to be borne out by the student experience. It is easy enough to interpret MAIN GATEWAYS or PATHS AND GOALS or QUIET BACKS; these patterns are (for the most part) not contrivances but a natural way of interpreting the built environment that any lay person could recognize.

The second hypothesis would have it that the urban fabric really is made up of patterns or pattern-like elements and relationships that are readily identifiable as such on existing sites; but when it comes to design, they are not the most intuitive building blocks to design with, for creating interlocking wholes 'at once.' (i.e. creating through design a final product embedding complex sets of relationships that in traditional urbanism grew up incrementally) This implies that it is natural to interpret a site using patterns (because they pre-exist), but difficult to intervene using them.

This hypothesis is compatible with the student work. It would also seem to tally with the experience of Modernist planning, many of whose advocates such as Hilberseimer (1944), Le Corbusier (1933/1964) and Bacon (1975) drew inspiration explicitly from traditional urban formats, but their designs always seemed to be simpler and less rich—and often less functional than the traditional exemplars (Marshall 2009).

According to the third hypothesis, patterns could be a valid, viable way for both interpreting *and* building the built environment, but the users of the book (in this case, students) sometimes find pattern language difficult to apply.

This could be because the students are preconditioned to think in terms of conventional building blocks, such as land use zones or neighborhood units; if those could be 'unlearned,' the students might find pattern language easier to use (hypothesis 3a). This could be partly true, but is unlikely to be a crucial factor. The students are not strongly indoctrinated into conventional planning; many students come to the course from outside planning (including UCL's BASc in Arts and Sciences programmes). It is possible they learned about town planning elements such as central business districts or concentric rings at school. In any case, in daily observation of a modern urban or suburban landscape, one is more likely to come across things such as 'shopping centres' and 'industrial estates' than 'Degrees of Publicness' or 'Scattered Work'. In traditional urban fabrics, element such as 'suburban high streets' are readily observable, though they are not found among Alexander's patterns, and it is therefore likely that anyone's first stab at a town plan would include those 'not in the book' features.

Another possibility (hypothesis 3 (b)) is that patterns are simply too difficult to think with; either because they faithfully reflect the difficult complexity of reality, or because they are in some way counterintuitive. According to this hypothesis, students find it difficult to conceive of the interlocking, overlapping nature of the urban fabric. This would correspond with Alexander's hypothesis in *A City is Not a Tree*. In this case, *A Pattern Language* provides an explicit way of 'forcing' the users to try to think in terms of what links to what, and what overlaps with what. These connections are documented (e.g. in the students' diagrams, Fig. 14.6), but they are not always easily grasped as a whole or expressed on plan. It may be difficult to express the overlap and interlock, perhaps because the more successfully a place or design is seamlessly constituted, the less visible the join becomes. In other words, patterns could in principle be a viable way of creating complex environments, but difficult to use; they overcome the creative challenge but are limited by a cognitive constraint. From the student experience, this is inferred to be at least partly true.

(c) Finally, it could simply be that the more able students apply patterns successfully, and the less able don't. This could be a straightforward case of ability equating with dexterity, like skill in drawing or handling numbers. The most able students not only 'get it' (understand what they should be doing with patterns and why), but are able to express themselves through patterns, as the exercise demands. The fact that some students do not do it so well could simply be a matter of natural variation in abilities. But it could also be that the students who 'get it' make their designs look as if they were designed using patterns, even if the patterns are retrofitted.[1] From the evidence so far, this hypothesis is not borne out. The students

[1]This doubt raises the question: Do students continue to use patterns later on in their studies, or do they revert to conventional design elements, such as a neighborhood, park or car park? Even if they do not use patterns again, students might benefit from the insights they have gained through

who were most articulate in their reflections on the design process were also the most articulate in pinpointing the challenges of working with patterns.

The nuances of difference or linkage between hypotheses 2 and 3 (a) and (b) could be further tested to better understand the degree to which any cognitive constraints affected the usability of patterns as building blocks for design.

Turning to the students' reflections on the strengths and weaknesses of using pattern languages, we find some clues about what was going on in the students' minds (Table 14.2).

Taking these points together, we can conclude that the use of patterns allowed the creation of complexity, but that, to some extent, that complexity was difficult to conceive and visualize. That is, *A Pattern Language* helped address the creative challenge proposed in *A City is not a Tree*, but the resulting structure was sometimes difficult to conceive and visualize. This could yet be an advance on conventional treatments that do not address the challenge of complex design (even if it does not solve the cognitive constraint).

Secondly, the patterns were not necessarily the most useful 'building blocks' to design with. This could be because regarding patterns as 'building blocks' implies breaking down the urban fabric into discrete elements—somehow leading to a loss of the seamless interlocking complexity of target urban fabrics. In other words, this could be an inevitable consequence of attempting to design with discrete objects.

Alternatively, it could be that patterns are, as it were, the wrong kind of thing to design with precisely because they deal with entities that are not 'things' as such, but more elusive entities that are not as concretely designable as more conventional units. It is possible that some students, in faithfully following the Alexandrian definition of a pattern, found those patterns unintuitive to design with, while those that 'converted' patterns into "handy things to design with" (discrete building blocks) improved the 'designability' of patterns but created 'clunkier' products. For example, the pattern PATHS AND GOALS is less tangible than the things 'footpath' and 'door'. This issue could be further tested.

As it stands, we can see why Alexander's system, at once traditionalist and revolutionary, gradualist yet accelerative, could appear so promising in principle yet remain underutilized in practice: The system as a whole would need a revolution to allow it to work. The implementation of a single pattern implies bringing into play several others, and even rethinking the whole system of how the built environment is designed and managed. In this sense, the most ordinary pattern could be more difficult to apply in practice than the most radical, innovative object; discrete objects can effectively be accommodated by the conventional system without changing it. An iconoclastic, avant-garde Le Corbusier chair, for example, fits perfectly within the system of furniture design, production and furniture retail markets, whereas a physically prosaic Alexandrian public bench built into the wall

(Footnote 1 continued)

using them, including the process of experimentation and alternative ways of thinking about urban fabric; some anecdotal evidence suggests this is the case.

Table 14.2 Student reflection on the strengths and weaknesses of patterns

Student	Comment	Interpretation
A	"It was very difficult to draw patterns on a map with boundaries."	While this statement contains some ambiguity, the words "very difficult" are unambiguous: There is some sort of barrier to visualizing or conceiving of patterns, including patterns at different scales—a NETWORK OF LEARNING could be city-wide or boundless.
B	"Using patterns […] on numerous occasions restricted our efforts. Oftentimes the vision became subservient to the pattern framework."	This student implies that patterns dictated how their vision could be expressed, rather than the vision being 'naturally' dreamed up in the language of patterns—like a "native language."
B	"Though a 'language' describes a consummate whole, it is difficult to envision the final product without being slavish to its constituent parts."	Perhaps, because the overall (site-specific) vision was itself not a pattern, the patterns only featured as parts of the whole. For example, if one had a SMALL PUBLIC SQUARE that was also an ACTIVITY NODE, it may have been difficult to conceive of this space as anything other than the sum of those two patterns.
B	Noted, as a strength, that the pattern method taps into "subconscious formations."	This statement was not elaborated on, but could have been a generic statement about the attributes of patterns in general, reproducing received wisdom on strengths and weaknesses.
C	"By carving things into patterns […] users […] focus too much on the actual patterns rather than their linkages."	This statement implies that patterns-with-linkages are the important thing, rather than 'building blocks' as discrete, separable elements.
C	The book presents a series of patterns but does not 'vivisect' an existing fabric (as Jane Jacobs did), which would emphasize the whole, including the connections.	Because it presents a series of separable entities, the *Pattern Language* book may itself be part of the problem. (This statement throws some light on the previous one.)
D	"A denser or more complex structure of patterns would be difficult to present in raw form to the layman."	This student alludes to the visual complexity of presenting design solutions as a limitation.
E	Patterns could "constrain thinking."	Patterns may constrain the user because they offer a limited range of solutions.
F	Patterns helped "expand the mind."	This implies patterns do not constrain thinking.
G	Patterns encouraged thinking in a 'piecemeal' way to create a 'holistic' vision	This comment could be interpreted as paradoxical, or alternatively, part of the quixotic appeal of Alexander's broader quest.

(continued)

Table 14.2 (continued)

Student	Comment	Interpretation
H	Pattern making is complicated and patterns can't be put together "in one second."	This reflects the traditional processes that pattern-making is inspired by; the implied time consuming complication may be the price to be paid for any benefits of 'better urbanism' resulting.
I	Patterns did not fit well with what this student was trying to do	This student had difficulty fitting abstract guidelines with an existing site.
J	"We refer to it now and then."	This implies that the pattern language was only partly used; it alludes to the periodic departure from the pattern-based approach, by using non-pattern elements, in the design.

of a private building could imply a complex renegotiation of physical, social and legal boundaries. To the extent that *A Pattern Language* upsets distinctions between conventional morphological objects and modes of production, Alexander's way of planning is itself cognitively challenging.

Ironically, then, patterns—while potentially offering a solution to complex design—seem themselves to suffer from the cognitive constraint, of themselves being too complex to work with. This difficulty in application is partly why, even though patterns have been applied successfully by individual designers, they have yet to become a new order that can usurp conventional planning—we still have city Departments of Planning, after all, rather than Departments of Pattern-Making. That pattern languages have not become the new mainstream also lends support to Alexander's earlier hypothesis: The limitations of Alexandrian methods in practice support the Alexandrian theory of 'cognitive constraint.'

14.5 Conclusion

This chapter reported on the use of *A Pattern Language* as a teaching tool in student projects. In doing so, it draws attention to some of the challenges of using patterns to generate complex urban form, lending support to Alexander's 'cognitive constraint' hypothesis—that people have difficulty in holding interlocking, overlapping structures in their heads—and therefore partly explaining the 'creative challenge' involved—the difficulty inherent in recreating the complex traditional urban fabrics by an act of design or planning. The challenges highlighted by the chapter suggest that more research is needed to demonstrate the relation between these aspects systematically: Further interrogation of designs and designers could help here.

Ultimately, there is a need for further development of ways to help make the design of complex fabrics more intuitive; or else, to create complex fabrics not so much 'by design', but through some sort of collective, incremental process.

This could perhaps be through the use of codes to handle the interlocking relationships between elements in the urban fabric (i.e. as anticipated in *A Pattern Language*), while the elements themselves could be more conventional (i.e. unlike Alexandrian-style patterns). In such a way, the overlapping, interlocking complexity is realised by the assembly of relationships, not built into the elements themselves. By this means it could yet be possible for different people to design parts of the fabric simply in a controlled but piecemeal fashion, building up complexity in a collaborative fashion, in a way that allows creativity while avoiding any cognitive constraints.

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Chapter 15
The Evolution of City Gaming

Ekim Tan

Abstract City Games as a method for city making, their evolution and future. Gaming is rarely involved in the creation of our environment, but has plenty of unexplored potential: games combine the social and spatial dimensions of self-organizing urban processes, and serve as an interface between more abstract decision-making and material city-making. City Games, designed for and applied to pressing urban questions, are a radical new tool for planning by playfully negotiating potential collaborations and existing conflicts between the real 'players' involved in each urban question. By transforming serious issues into a playful and engaging (although no less serious) experience, city gaming unlocks difficult conversations and helps build active communities. Parameters provided by topological data can be combined in an operational form in gaming, while social and design parameters are extracted from it: the interactive and iterative nature of city gaming encourages the development of collective intelligence derived from the real lives of players. The data comes together at the end of the game as an urban game plan. Play the City Foundation presents Generative City Gaming: an innovative urban planning and design method built on the tradition of serious gaming. This paper traces the evolution of City Gaming through site-specific case studies.

15.1 Games for Cities

Games can be defined as structured forms of playing, while play is a form of intense interactive and collaborative engagement, free from real material interest or material gain. In his 1938 book *Homo Ludens,* the Dutch philosopher Johan Huizinga

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identifies play as necessary condition for culture to emerge: “Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing.” As structured play, games rely on clear and simple rules, which guide players through set challenges and interaction patterns to reach predetermined goals. Today, an increasing number of games are played for serious purposes: defense, education, scientific exploration, health care, emergency management, city planning, engineering, religion and politics are just some of the fields within which gaming has found a role. Also known as ‘serious games,’ such simulations of real-world events or processes are designed and played for the purpose of solving a problem (Abt 1970). Although serious games can be entertaining, their main purpose is educate players about a particular problem and train them to find solutions.

The works of architects Constant Nieuwenhuys and Cedric Price include game-like urban environments designed to be activated by citizen engagement. Later in the 1960s, serious gaming emerged in the field of urban planning for the purpose of problem-solving. These first urban games typically revolved around topics such as land use, community development, public participation, city management, transportation, ecology and natural resources. Some of these games were politically oriented, played by regulators to negotiate public budgets. Richard Duke, the father of planning simulation games, created *Metropolis* at the University of Michigan for the Lansing City Council of Michigan State (Duke 1966). *Metropolis* is a planning game in analog format, created to engage members of a city council in urban development plans (Duke 1995).

Following advancements in computer technology, more planning simulation games adapted mathematical models to refine their representations of complex environments. As the development of these models relied on the growth of computation technologies, it is no coincidence that they were geared towards processing a wide range of the quantifiable aspects of cities: economics, demographics, technical factors, transportation, mobility and urban growth, among others. The seventies witnessed an avalanche of simulation games for land use and price planning as hyper-comprehensive ‘large-scale urban planning models’ (LSUMs) were built to predict complex urban futures; Duke’s Metro and Metro-Apex, following versions of Metropolis developed during this period, were the most used games for training, learning and prediction (Malgorzata 2007). These games flourished at a time when many planners believed that it was possible to model a major metropolitan community with a predictive, scientific tool in order to evaluate how various proposals would affect the community (Duke 1966). This later proved to be a rather simplistic view, limited both in theoretical and technological content. The ‘Limits to Growth’ simulation model proposed by the Club of Rome (Meadows and Randers 1974), the workings and limitations of which also belongs to this school of thought.

The planning games of the sixties and seventies typically assumed an urban system controlled and ordered from above. Likewise, data selection, its correlation with other datasets and equations simulating urban complexities were neither influenced by nor made known to players. It was precisely these properties, and specifically their top-down treatment, that eventually backfired. When the social planning crisis of the eighties was coupled with rising skepticism about the accuracy of the computation of social complexities, most of the serious gaming research was put on hold. It became obvious that reflection was needed on the setup of planning games: they could not function as closed models, a sort of black box for socially generated data. From these early errors of gaming, questions arose which are fundamental to this research: Could games function as open systems, just like the cities they simulate? Could they integrate unexpected internal and external conditions, and eventually adapt based on these inputs? Could they integrate the complexity of human agents into the process of prediction to improve the accuracy and applicability of the results?

Such trial and error episodes are inherent to the emergence of new methods. While the eighties and nineties saw diminishing numbers of scientific articles on urban gaming and fewer planning games being played, the rise of self-organization theories at the turn of the century offered new perspectives for gaming; hybrid forms such as 'free-form games' (Mayer 2009), in which human beings as complex agents combine computation with their own unpredictability, opened gaming up to represent society's complexity. The most visible transformation of games towards representing social and urban unpredictability could be observed in the best-selling planning game SimCity, launched in the eighties. Identified as a 'god-game', SimCity challenged its players—each the mayor of their own city—to build cities from scratch then strategically manage their growth. The game was originally designed to simulate a city organized in a top-down manner with predetermined zoning norms built into the game. However, the latest release of the game in May 2013 opened up the system to allow multiple players to interact with one another while governing their cities. This single change has transformed the game into a semi-open multiplayer environment in which unpredictable player interactions can influence the game process. And the agency given to players by this change has expanded beyond the game platform: Players have built a wiki community to exchange knowledge on the process of playing. Player collaborations thus influence the process, content and design of the game, evidence of the effective use of collective intelligence both inside and outside the game platform. Advancements in systemic thinking and ICT, and a changing view on how cities self-organize from both above and below, have helped SimCity to become a more open and evolutionary game environment. SimCity's latest release is a reflection of the fact that these theoretical and technological advancements are relevant and being embraced by popular practice.

15.2 What Are City Games?

City Games were suggested by Juval Portugali (1996, 2000, 2011) as a tool to illustrate and examine self-organization in the domain of spatial cognition. Today, from war-gaming to gaming for education, simulation, prediction, collective intelligence and policy making, a new field of gaming-stimulated knowledge-production is increasingly evolving, through a process of trial and error that embraces the complexity of the fields it addresses. While gaming for the purpose of training, strategizing and learning is already widely trusted, the scientific foundation of gaming for prediction and policy-making is still subject to questions, as expressed by Mayer. Given these foundations (still being built, but increasingly solid), the pressing question for the field of planning is whether gaming can serve as a method for collaborative decision-making and the co-creation of urban environments. Can gaming be harnessed to guide planning from the seeding of ideas to implementing the plans on the ground? Beyond feeding decision-making, can gaming become operational in the producing and implementation of collaborative urban schemes? These questions, if answered in the positive, imply that gaming could become a permanent part of the city-making cycle. Collaborative planning through gaming could take in every part of the process from decision-making to participatory budgeting, crowd-building and maintaining cities. Going one step further: Could City Gaming bridge the gap between a theoretical understanding of cities as nonlinear, unpredictable and complex processes, and their treatment in practice as linearly produced? Could the direct implementation of game outcomes work in practice, as a new form of complex yet socially engaged city-making?

The use of games for city-making purposes would require a gaming method that is designed to do more than teach, train, strategize, predict and entertain. Because of the extra step—of taking gaming beyond the table and into reality—I call City Gaming designed for practice *Generative City Gaming*.

Building on the tradition of serious games, Generative City Games focuses on real complex urban problems. In contrast to serious gaming, however, Generative City Gaming integrates the design and decision making dimensions, the social and political structures of cities, and the topological context in the design of the game. The game thus becomes a generative medium for making and maintaining (real) cities, because by mapping the city's particularities, it gains the capacity to respond to the quirks and needs of its users and spaces; Generative City Gaming is built to respond to real-world complexities. The problem-solving capacity of City Gaming become clear when applied to urban questions in which multiple stakeholders with various conflicts and interest are involved, such as how to develop a new city expansion, renew an existing neighborhood, regenerate a train station node or encourage smart grid adoption by local communities to support a government's energy policies. As long as there are multiple stakeholders with clashing interests involved, the City Game method offers a way to resolve these and develop a cohesive plan collaboratively. Real urban urgencies define the narrative of each game, while existing power balances between politicians, technocrats, the market and community will determine each game outcome's potential for implementation. The second half of this article introduces Generative City Gaming experiments played between 2008 and 2013. Instead of detailing all City Games individually, this chapter focuses on the evolution of six selected cases which helped build the method, refining and challenging the original tenet through failures, successes and surprises—and laying the groundwork for future experiments.

15.3 The Evolution of City Gaming

Since 2008, when the first City Game was organized in Almere Haven, the method has evolved significantly. The main aim of this work has been to facilitate a given urban question through a game environment by bringing together the right stakeholders and, through a game tailored to the question, influencing the urban reality. Based on these touchstones, the successes and failures of each game were recorded, and the lessons learnt from them applied in the design of the next City Game, to help the City Gaming method to develop and improve. The very variety and unpredictability of the cases tackled by the method has provided a steady input component, testing the game against urban realities and helping it to evolve in response. The final chapter of this research will report on the evolution of City Gaming since its inception and the questions that have guided its development: How has the capacity of City Gaming improved through its applied experiments? What was the role of rules in the evolution of the method? What organizational and design rules evolved during the game, and for which purposes? What are the right interest groups to join the city game? The first game was played with students simulating residents; why and how did more urban roles get integrated into the game? Where does the urban narrative stand in this development? What are the common denominators of the various urban complexities? In response to which urban questions does City Gaming become more effective?

To conclude, the potential and limitations of the method will be discussed. The chapter will end by posing open questions about what steps the research can take to further advance the method. These improvements will build on what the research has shown to date, both in terms of its own process and its successful adoption in the implementation phases of real urban processes.

The first City Gaming experiment, *Play Almere Haven*, conducted in 2008, was inspired by Christopher Alexander's iterative design processes as well as Juval Portugali's city simulation experiments with scale models observing self-organization principles at work in an urban context. Likewise, the purpose of the Almere Haven experiment was to test principles of self-organization on Almere's urban extension plans. While the new town's policy-makers desired the active contribution of Almere's existing and future citizens in the shaping of the new plan, they lacked the necessary methods to organize such a process. Could a City Game simulating self-organizing urban growth become an alternative participatory process for the city of Almere? Rather than aiming to produce a fixed master plan, the Almere Haven game set out to test whether a process guided by simple rules could result in an open-ended evolutionary plan that reflected the complexity of urban development. The players, international students from various academic disciplines, followed simple rules of sequential play, respect for choices and urban density to lay out their ideal settlement as simulated future residents of the area. As a result of intense interactive play, a diverse but collectively agreed plan emerged, reflecting the heterogeneity of the players. It was promising that a City Game could produce a readable urban plan as a final outcome. However, the low level of

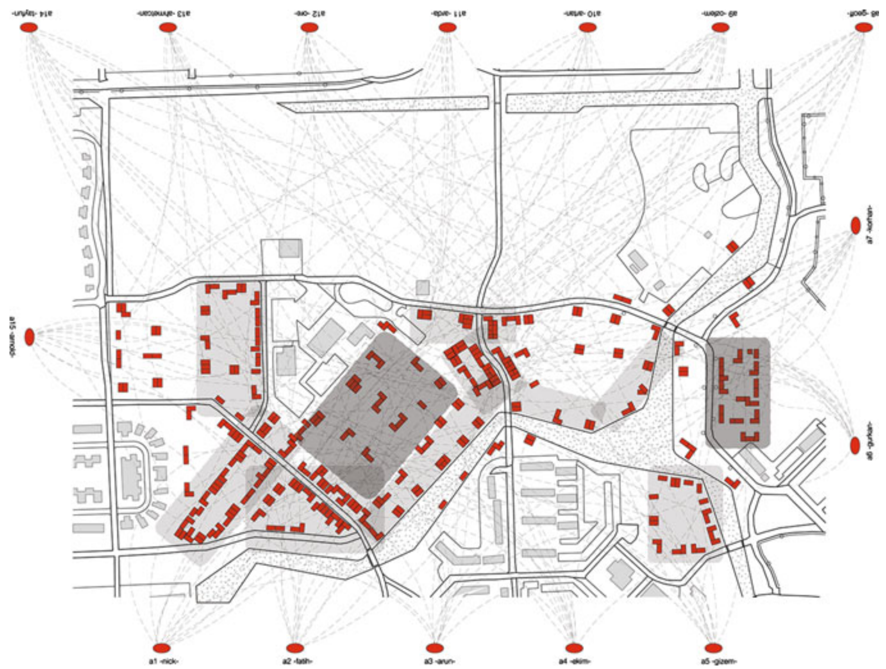

Fig. 15.1 Play Almere

elaboration in the plan and a lack of design was evident. Furthermore, students from large metropolises such as Istanbul, Nairobi, Mumbai, and New York were role-playing as hypothetical future residents of a lower density Dutch new tow; these students brought their tendencies for high-rise and higher densities into the game, tendencies at odds with the suburban character of Almere. For further details see Tan and Portugali (2008) (Fig. 15.1).

Nevertheless, the result of the game could not be projected onto Rotterdam's reality as an urban plan. The amount of research and understanding which the foreign architecture students could acquire during the two week summer-school workshop was insufficient to make the result sufficiently nuanced and incisive. This prompted us to think about how best to engage real stakeholders, with a view to harnessing local knowledge and so making the urban plan resulting from a local game applicable to the real issue 'played' in the session (Fig. 15.2).

The third City Game, *Yap-Yaşa*, tackled the urban transformation of Istanbul. In it, I took the step of including real stakeholders from three of the megapolis' self-built neighborhoods. Although the analysis of the Rotterdam game had provided guidance and parameters as to how design could become part of the play process, few of the *Yap-Yaşa* stakeholders were designers by training. I therefore needed to take an extra step; the game design included modeling a city block, or 'Yap-Yaşa' block, the basic unit which makes up over 70 % of Istanbul's urban fabric. *Play Yap-Yaşa* proposed this block as the operational unit for Istanbul's

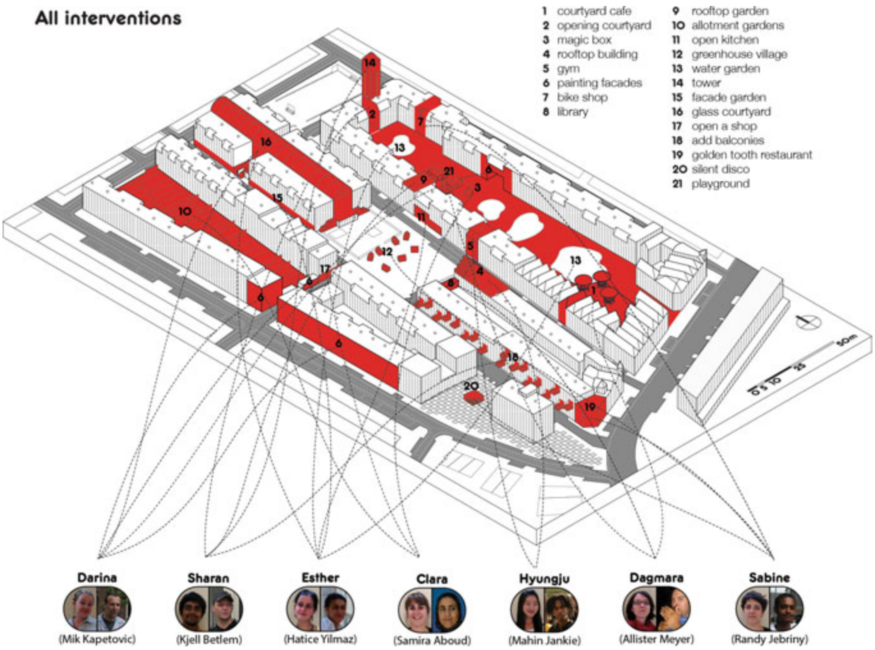

Fig. 15.2 Play Oude Westen

urban transformation. Using parametric design—in which design is guided by rules—was the obvious next step for a game system based on organizational rules and aiming to reach a designed urban order. By distilling the key design options available to players into rule-based parameters, non-designers who were taught the game's guidelines for city block transformation could focus on expressing their own interests and visions for the block (expressed through a palette of choices with 'design' designed into them) rather than trying to contribute new design ideas in the game—a daunting and potentially limiting challenge for non-designers which could detract from their deeper involvement in discussing the site, and applying their knowledge of it. In other words, beyond having an understanding of the design rules, players were encouraged to concentrate on expressing their own interests. Design rules proposed by experts served as an interface for collecting design feedback from stakeholders who do not have the training or the ambition to contribute to the formal expression of their urban environment. Using simple rules created with their specific environment in mind, non-designers could articulate their visions, reflecting their cultural, social and economic conditions, in material terms. These rules also allowed them, and their proposals, to interact on an equal footing with designers and theirs. Thus *Yap-Yaşa* offered the language of gaming and simple rules as an interface to empower both design experts and non-designer stakeholders to negotiate with one another (Fig. 15.3).

Fig. 15.3 Yap-Yasa

By relying on parametric design, *Yap-Yaşa* facilitated a broad range of real roles, from the national housing corporation to local authorities, private and public sector planners, investors, mediators, urban designers, architects, neighborhood resident organizations and activists. Another innovation in *Yap-Yaşa* was the introduction of the role-exchange method. During the preparation of the City Game I understood that the urban transformation agenda of Istanbul was highly polarized. Bringing players together with severely clashing interests—such as a tenant in a gecekondu whose house is to be demolished by the transformation plans playing alongside a representative of the national housing corporation institute who mobilizes the contractor firms to implement new high-rise blocks replacing the gecekondu homes —was only possible by asking them to take on each other's roles to moderate the conflict. This method, inspired by role-play in gaming, allowed the City Game to include real stakeholders while offering them a shift in this very reality: the opportunity to both role-play and apply their own experience to a scenario through the imagined eyes of a present 'other.' Despite the fact that some of the stakeholders of the urban transformation normally refuse to be in the same room as others, let alone listen to one another and act collaboratively, the role-exchange method worked well. The City Game as an interface succeeded in gathering these players around a city model, and role-exchange helped them to open up and talk about very delicate issues such as eviction and the demolition of the earthquake-sensitive neighborhoods. Such confrontational debates are mostly avoided in Istanbul unless absolutely necessary, such as in a court case. The game condition, as an exceptional state which served as an escape from the difficulties of everyday reality, made space for free-thinking, open discussion; *Yap-Yaşa* brought together the disparate stakeholders of Istanbul's future while confronting them with their 'real' conflicts, albeit formulated as and mediated through a playful interface.

The parametric design principles implemented in *Yap-Yaşa* were later applied in the fourth City Game, *Play Noord*, which addressed the disuse of the former Shell research laboratories, a derelict urban site in the Amsterdam Noord district. After Shell left the buildings, the area had been ambitiously planned as a high-density mixed-use area for higher-middle income groups. The plan was legally approved by the local authorities, but came to a halt after the 2008 real estate crisis. Compared to *Yap-Yaşa*, the game tackled a more concrete urban question with stakeholders open to conversation, promising a better chance of the game outcome being applicable directly to the site. From alderman Kees Diepeveen to the environmental activists Angsaw, the Noordwaarts project office and over 100 other stakeholders, the players of *Play Noord* welcomed open debate. As the local authorities were not willing to hold the debate for alternatives to a frozen legal plan within the walls of the municipality, an external agent, such as a City Game could start the debate. Due to the willingness of the stakeholders and their tolerance of each other's positions, real stakeholders could defend their real interests in *Play Noord*. This was in contrast to *Yap-Yaşa* where stakeholders represented the interests of other players. This contributed to the accuracy of the game outcomes. However, I implemented one extra layer in the mapping of stakeholders for this game: including potential small and medium scale entrepreneurs who show interest alongside existing large-scale investors and corporations who hesitate due to financial risks. As in reality the 'big' players stepped back from the project and acted conservatively to avoid risks. I was curious to observe how alternative smaller size enterprises could tackle the same program.

Due to the public attention that the City Game attracted, my team created a digital public evaluation poll that enabled both the players and the engaged audience to vote on initiatives they supported. The projects with most audience votes stayed in the game and could continue to grow. This game also developed the guiding roles of the politician and the activist with vision-setting and the power to veto. The politician could give public vision speeches when he or she saw the need for setting a collective direction, while the activist could use the veto card to stop an initiative when more than half of the players supported the motion.

The challenge of reaching a larger number of players was taken on by expanding the debate to the digital polls, and connecting both the polls and the game to a social media website which broadcasted the opinions and plans proposed during play. This process helped to spread the outcomes of the game to a wider public who could later become part of the game by discussing it on the social media website where ideas could be shared and developed collectively (Fig. 15.4).

Shortly after *Play Noord*, the game was applied to The Hague's Binckhorst neighborhood, where a succession of masterplans had failed after the financial crisis. Half a year later, the City of Tirana and Polis University, Albania, requested a the City Game—as *Play Tirana*—to gather public opinion on the design of a new train station at the northern end of the city center. The digital element of *Play Noord* was adapted into a governance poll game for Istanbul a year later, called '*If I were the Mayor of Istanbu*l.' At playthecity.eu there is more information about these cases. This chapter does not analyze these 'repeats,' as they are practical

Fig. 15.4 Play Noord

applications of the existing method without additional innovative properties. It is important to note, however, that local applications of the same City Game result in different outcomes, given that urban rules and conditions vary, as do the players, their powers, interest and conflicts.

Play Oosterwold was commissioned to test the rules guiding a Do It Yourself urban plan while still in its design phase. We set up a City Game to observe how players tackled the challenge of providing and maintaining adequate public amenities with private resources. According to the plan rules, public services such as local roads, energy and water were to be provided by individual residents in Almere's Oosterwold neighborhood. This required the integration of currency and value into the game process for the first time. Introducing money as a parameter highlighted an existing conflict between local and central authorities about the land values in Oosterwold, and sparked a debate about spatial quality and social value versus economic imperatives within the game (and, by extension, within the neighborhood). In response to this guiding parameter, players started developing real-estate trades such as renting out facilities and setting up local businesses—a step beyond the game's initial premise that players invest in land, plan services, then build. The introduction of a broader economic aspect to the game was not engineered by the game designers, but developed by the players themselves (Fig. 15.5).

As hundreds came to play Oosterwold in round after round of the game, they learnt about a new way of developing land in Almere by simulating the opportunities self-build afforded. Due to the large volume of demand, the game was played with different stakeholders as part of the Making Almere show for over two years. Our local game master oversaw over 50 game sessions involving over one thousand individuals—the greatest reach of a single City Game to date. As players got acquainted with the rule-based plan, I observed the play patterns of potential

Fig. 15.5 Play Oosterwold

Oosterwold residents and pointed out loopholes in the existing plan's rules to them. Thus, besides experimenting with currency and economic flows in *Play Oosterwold*, I learnt the importance of being locally embedded over a longer period for the game to achieve a greater impact. This also allowed us to observe patterns in the process of play and generalize site-specific behavioral traits, to offer the designers of the plan detailed feedback on their rules and parameters.

In contrast to previous City Games, *Play Van Gendthallen* was focused on monumental architecture rather than urban design. A group of small-scale creative enterprises who were searching for an affordable and inspiring workspace activated the Van Gendthallen City Game. The development of these listed monuments was brought to a standstill by the ongoing financial crisis. The twenty groups involved loved the historic complex, even in its dilapidated state, and did not mind working in disadvantageous physical conditions such as a leaking roof and the cold of Dutch winter. They came together to organize and build a temporary town to work in over three months. Individually, they had clear plans for their initiatives—whether it was setting up a business, workshop or performance space—but they required an overall shared vision for the 3000 m^2 area in the form of an implementable plan that would be acceptable to all parties; for the first time a City Game was confronted with the challenge of implementing the game outcome immediately after play. A 1:30 scale model of the historic halls was built and all players were individually consulted and advised as they created individual scale models of their initiatives. Once these were ready, the play session began. It lasted for three days, until the participants reached outcomes they could all agree to build collectively. The players of the game were also the designers and builders of the initiatives in the temporary town. The direct implementation and focuses aim helped the City Game in two ways: the rules of the game could be discussed and changed according to the players' interests (since the players were also the clinets), becoming the first instance of flexibility in the adaptation and creation of rules in a City Game; the immediate relation between those playing the game, those making decisions and those applying them to reality meant that, once discussed and mediated through play, the game outcome could be successfully implemented in the three months following the play session.

In addition, building a detailed scale model as a game interface and conducting intense consultation with all players before the play began helped ensure the success of *Play Van Gendthallen*. This game differs from previous ones in two important aspects: the immediate implementation of the outcome and the scale of the development. This was the first game that functioned on an architectural level, in contrast to previous games' focus on the scale of urban planning and design (Fig. 15.6).

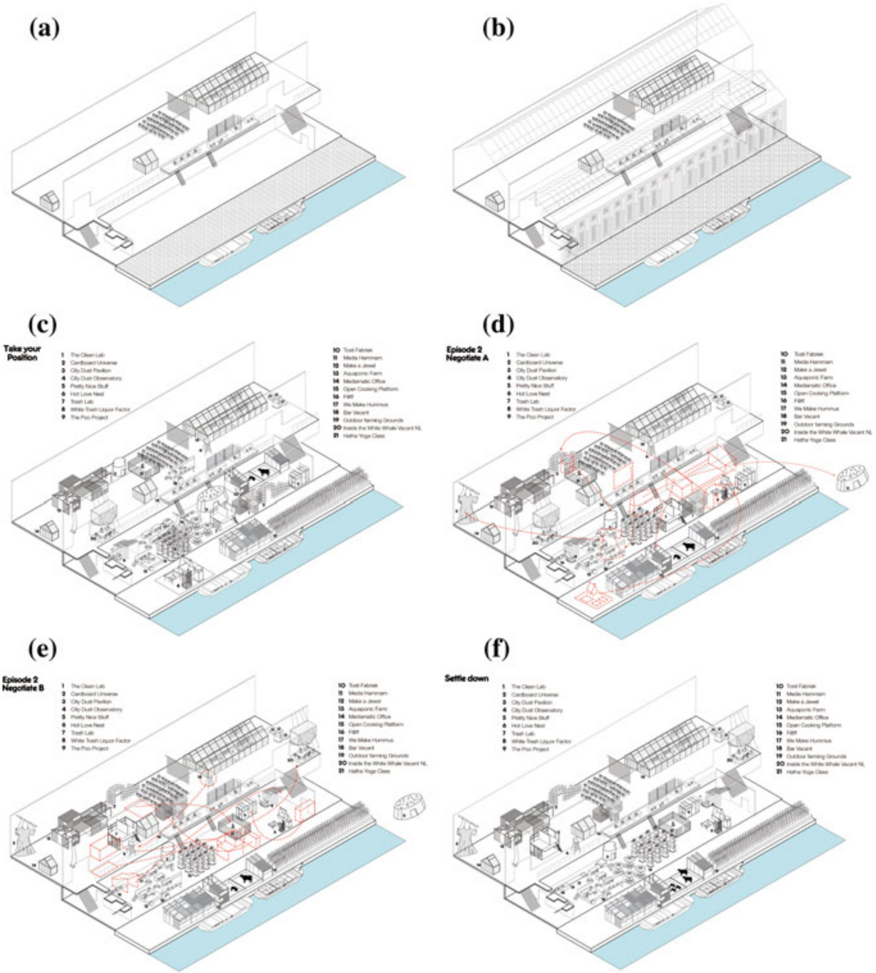

Fig. 15.6 Play Van Gendthallen

The City Gaming method has evolved tremendously, from a hypothetical simulation test about how self-organization principles could help order a new town expansion in 2008, to a complete game outcome implementation in 2012. The method's evolution was inspired in part by the questions raised in the process of answering others. The next section outlines how such an evolution occurred, considering components of the City Game—such as rules, roles and narratives—independently.

15.3.1 Evolution of City Gaming Rules

The first game, *Almere Haven*, was guided by four simple rules of play. The first rule, requiring **sequential** play, was set to ensure an iterative process where all players observe each step taken and react to the course of the urban dynamics developing in the game. The second rule, on **respect**, was included to protect the decisions made by players in the initial phases of play from later developments; new moves which would conflict with earlier ones could not simply overturn them, but had to establish themselves within the existing context by lobbying the other players and finding an acceptable position which coexisted with material already on the play table. This rule enabled the coexistence of diverse orders side by side, and encouraged negotiated distances between players' moves. The third rule determined **density, and** was needed to clarify the spatial challenge on an abstract level. A given program was defined as a number of game units in the design of the game to help represent the reality of a given urban question. Players were given the freedom to distribute these units themselves in the City Game. A practical application of the density rule is to mark the end of the game sessions—which is open-ended by nature—when a particular density has been reached or a programmatic requirement met, The fourth and final rule required unblocked **access** to all proposed urban units, a design rule that not only influenced the positioning of households but also shaped the street network.

The second game, played by seven international architects in Rotterdam's Oude Westen, initially adopted the simple rules of *Play Almere Haven*. However, the architects soon felt the need to evaluate the spatial quality of each player's iterative design steps, and brought in a fifth rule—requiring **approval** through group voting for each of these. Players also invented the **public intervention** rule for proposals that affected public space: any discrepancy between individual visions regarding the collective space was resolved through the rule of a majority vote. This rule required clarification, distinguishing between fulfilling the desires and needs of an individual and reaching a shared vision for the urban development. This rule was lacking in Almere, and on reflection, its outcome was a collage of various fragmented orders as a result. In Rotterdam on the other hand, players achieved a strong, coherent overall design proposal, with a legible collective vision of opening up inner courtyards to create an exclusive alternative pedestrian mobility system—and the rule of public vote implemented by the players themselves was key to achieving this.

In *Yap-Yaşa*, the respect and density rules were kept the same while I tested **simultaneous** play instead of sequential play. In earlier City Games, the sequential play rule provided a recognizable design order through an iterative play process. The *Yap-Yaşa* game, however, was designed to resolve the conflict between central authorities and local residents regarding ongoing urban transformation rather than requiring players to come up with a unique design order. Furthermore, not all the game agencies were building: there were also policy makers and activists who facilitated policy-making while seeking consensus and shared visions amongst all players. The simultaneous actions of builder and non-builders worked well for this City Game.

Yap-Yaşa employed rules that influenced more than just the final composition, as implemented in the previous two games. Its parametric design rules—such as demanding a proportion of **green space**, a rule limiting **height**, another ensuring each block had a public **gate** to its inner courtyard and one ensuring 50 % of the block was built by independent citizens—directly informed the design of the city block. The application of the parametric design rules resulted in formal variations on the board, which was a generic Istanbul city block. The '50 % rule' regulated the proportion of outer to inner area of the city block based on its ownership, maximum height and urban form. While the outer skin was generated by the housing corporation based on a repetitive order, the inner parts of the block, amounting to half of the built volume, was left free of the housing corporation's influence to be formed according to the vision of individual entrepreneurs. The 'green rule,' a design rule for unbuilt spaces, imposed a minimum of 40 % continuous public green space on the ground level, while all facades of the new Istanbul block were required to include a public gate leading to the green inner courtyards that formed as a result of the rule. The 'gate rule' was aimed at the housing corporation and the 'green rule' at the independent developers, making them interact through the public realm. An interesting result of *Yap-Yaşa* was that a rule designed to organize the design, the '50 % rule,' was very influential in resolving the conflict over the transformation of the urban block. The two fronts of the urban transformation debate, whose disagreement in real life is mainly due to the unjust distribution of decision-making power, started interacting and even collaborating after the this rule came into play. By allowing homeowners to join in the construction process and so take part in the transformation of the city as individual entrepreneurs, this rule provided evidence that part of the resistance is against lack of involvement and not against change per se.

The combination of simultaneous play and parametric design rules as well as the involvement of non-builder roles continued in *Play Noord* after their application in Istanbul's *Yap-Yaşa*. The time needed for each game session could be optimized through simultaneous play, leaving more time for open debate. Two new rules were added to the respect and density rules in *Noord*: the **veto** and **collaboration** rules. Either the politician and the activist could activate the veto rule, the former using his veto card directly and independently, while the latter needed a majority to veto projects. This rule helped players to highlight sensitivities and conflicts, and openly negotiate them during play. In some cases, players were able to negotiate common ground and collaboration out of an initial disagreement. *Play Noord* was designed to debate a master plan that was on hold due to large corporations pulling out of a contract with the city of Amsterdam worth about 250 million euros. As a result, the City Game was built around whether, and how, small and medium scale entrepreneurs could be organized to activate the frozen urban plan. A second rule encouraging collaboration was introduced to ensure that small and medium scale stakeholders could form larger scale initiatives in line with the original plan.

Play Oosterwold was built to test the rules of a self-build urban plan for Almere's Oosterwold polders. For this game, I translated the rules proposed by the urban plan as 'building' rules for the City Game. These specific rules prescribed the entire process of settling in the polders, from selecting a plot to building access roads, and prescribing density and land use. These rules were communicated through infographics informing the game and parameters printed on game pieces. While the density and land use rules—both affecting private ownership—were implemented flawlessly, rules concerning water and access roads—shared ownership—needed adaptation by players to become functional.

The most direct of all the City Games in terms of the players' involvement was *Play van Gendthallen*. Before the game, our team conducted an intensive consultation with the players, who were also the clients and builders. The players, for the first time, negotiated setting their own rules of play. They created the '**iteration** rule' to ensure a realistic outcome would come out of three game sessions building on each other. Instead of the veto rule—designed to be activated by players such as the policy maker or the activist, who were not represented in *Play Van Gendthallen* —we introduced the '**conflict** rule,' which mediated any clash of interests between enterprises over the limited amount of space available for each player. In case of conflict, the game master could call for a referendum to organize collective decision-making. As a reaction to this rule, players who valued self-regulation over the judgement of the game master proposed to resolve conflicts with other players, without the interference of an external party.

The players also proposed rules about the financing of the construction; Mediamatic, the host organization, offered each player a budget. An accompanying '**tax** rule' emerged for initiatives that made commercial profit from partaking in the temporary town—these would give a percentage of that back to Mediamatic. Mediamatic in turn put forward a '**public engagement** rule,' which gave priority to initiatives with the greatest public visibility and engagement capacity, allowing them to play earlier in the sequence. Players saw the logic of this rule and added the '**priority rule'** for collaborating teams who would optimize use of space, material and energy during the implementation phase. The players were able to reflect productively on self-organization, many because of their previous experience with it in their professional, political or artistic activities. The culmination of this collective reflection was the proposal by one of the players to organize the town without having to refer to 'play rules.' The group named this the '**Rule of Rules**.'

This final rule captures well the open nature of City Gaming as a method whose human agents can influence and innovate its dynamic rules. I witnessed players inventing new rules or adapting existing ones to their needs through the gaming processes of *Van Gendthallen*, *Oude Westen* and *Oosterwold*. This final rule that no rule is fixed and all rules can be subject to change whenever they lose their relevance might indeed be a meta rule for all the games. Or, equally, it may reflect an underlying principle that had underscored the process from the start but had not, until this last session, been explicitly stated.

15.3.2 Evolution of City Gaming Roles

Since the first game, in which students simulating residents, new roles have been modeled for each iteration of the generative City Game. Addressing the urban transformation of Istanbul required representing a large range of stakeholders, from national and local authorities to NGOs, market parties, planners, designers and the residents of the self-built neighborhoods. In addition, resources representing the non-human drivers of the transformation, such as money, legislation, knowledge, skills, time and networks influencing the urban environment on a range of scales have been introduced to simulate Istanbul's urban complexity. The role modeling invented for Istanbul could be adapted for *Play Noord* after studying the site and current situation. Every case and site has its own special character, and paying attention to modeling particular roles and their impacts is vital. One important aspect to note when tailoring these generic roles to a new game is how the titles and actions of the players within any one organization vary; in municipalities, for example, there are city officers other than the alderman who are publicly silent yet very influential in decision-making processes. Tracing these or analogous characters, modeling their behavior and including them in City Games has proven to be a small but significant detail.

Interactions can take place between agents of same kind, such as the residents of Almere Haven, designers in Oude Westen or creative enterprises in Van Gendthallen, but can also imply negotiation between disparate agencies, as was the case in Istanbul, Noord and Oosterwold. Resolving conflicts or building consensus between agents with a variety of powers and interests requires a higher level of complexity. Not only must different interests be catered for when modeling relations between the players; potential clashes or collaborations between different powers must be taken into account. This variety and heightened relational complexity might have a positive impact on the applicability of a City Game. In *Play Van Gendthallen*, for example, players' interests varied and even conflicted with one another despite them being a similar 'type' of agent; by triggering negotiation, player conflicts ensured that all players were committed to the final, much debated outcome.

15.4 Limitations of Generative City Gaming

The Generative City Game method aims, ultimately, to introduce game outcomes directly into the real urban processes they address, or even feed the game outcomes itself into the principal planning process. The conditions of each case, such as its reliance on existing decision-making mechanisms, rules and regulations, or the balance of power between the involved parties, may hinder the link between the game and the reality it aims to influence. In addition, internal dynamics such as the constrains of digital technologies, inequality between players or deviation from the aim of the City Game can all impact on the performance of the City Game. Acknowledging the limitations of the method is essential for forecasting the possible impact of a City Game as accurately as possible, as well as reducing the hindrances it might face.

15.4.1 Power Play

City Gaming integrates existing power relations into the dynamics of play. This helps to visualize urban processes realistically and take into account existing interests. Nevertheless, however accurate and relevant the outcome of a City Game may be, the real and sometimes shifting power relations of real urban processes are the dominant factor influencing whether the City Game outcome can have a real impact—what I call making the jump from game to reality. A collaborative method such as City Gaming invites all players, from the traditionally differentiated realms of bottom-up and top-down influence as well as from the less defined reality between these, onto an open playing (and planning) field. Matters usually determined by experts behind closed doors become negotiated and even generated by other parties; information that is normally limited to circulating within the walls of the municipality buildings reaches a wider public—most importantly the population of that municipality—helping them make better informed decisions on matters of public importance. This openness, then, encourages local authorities to share their powers of decision-making and plan implementation not only with large corporations, as already occurs, but also with emerging small and medium scale market parties, as well as interested individuals and organizations. Sharing information is sharing power, which both diffuses and creates tension; all collaborative city generation methods require special attention in the implementation phases to negotiate the new balance of power, and City Gaming is no exception.

Not only does the City Gaming method question the position of the local authorities, but also that of experts, such as the designer. It suggests a reorientation of both towards collective and open intelligence. Whilst recognizing the importance of expertise, I emphasize the fact that urban environments evolve as a result of the interactions of all involved parties: experts and non-experts. Designers should not, because of their technical knowledge, gain power to single-handedly determine the form of the city. Rather, the designer should be one participating party influencing the urban negotiation process, and thus urban outcomes, with his or her particular expertise. Designers' specialized knowledge makes them more influential in forming and programming urban areas, but in the game process their *interaction* with other stakeholders—rather than a simple delivery of a finished plan to them—is fundamental.

However, the perception that traditional participatory processes undermine the creative capacity of a designer creates resistance within the design and planning profession. This is an attitudinal limitation for the inclusion and normalization of the gaming method among architects and urban designers. What needs to be stressed here is the intertwining of organizational and design rules, giving these professionals a key role in the design of the *process*, if less of the plan; to guarantee a certain level of design quality, designers must propose rules for City Gaming that will drive the spatial coherence of the overall outcome, even if this is negotiated and implemented by non-experts.

City Gaming's impact on a given urban question is to a large extent dependent on the political and cultural background of the project or site it addresses. Some local authorities already work in increasingly transparent environments where even public budgets are managed by communities through participatory budgeting, as in Porto Alegre in Portugal[1]. Other cities however, regard publishing master plans publicly as undesirable, or even illegal—as in the City of Astana, Kazakhstan. Mostly, local governments who have power over their region's land use plans do include phases of public consultation, as either a formal or informal procedure. City Gaming, theoretically, is a form of public consultation that can be applied within a range of planning regimes, from polarized and opaque planning procedures such as that of Istanbul to flexible planning cultures, such as the two sites in Amsterdam. However, as shown by the six examples presented in this chapter, whenever City Gaming is applied to a specific urban question, what the method can achieve is redefined by the political and social frameworks it functions within.

The involvement of various interest groups in any planning process is a move towards a more pluralistic approach and outcome that, if not well managed, can result in excessive competition that can be detrimental to both the policy-making and plan implementation processes. There will inevitably be instances of groups being more interested in advancing their own agenda than in advancing public interests; the practice of involving interest groups to ensure genuine representation also comes into question. The most influential group, the one with the greatest bargaining power or that which is best organized may not necessarily be representative of a wide spectrum of citizens. To tackle this limitation, City Games

[1]*Participatory budgeting (PB) is a process of democratic deliberation and decision-making, and a type of participatory democracy, in which ordinary people decide how to allocate part of a municipal or public budget. The first full participatory budgeting process was developed in the city of Porto Alegre, Brazil, starting in 1989.*

require a wide range of players or interest groups to play, and iterate as many sessions as necessary to reach the widest possible engaged audience—in *Play Oosterwold* over 50 sessions were played, whereas for the closed network of stakeholders in *Play Van Gendthallen* one extended session sufficed. City Gaming attempts to further even out the limitations inherent in public representation by a process of prior 'stakeholder mapping,' and by implementing rules that maintain public debate at the heart of the process.

15.4.2 Responsibility

The question of who takes responsibility for the outcome and its implementation can be problematic for collaborative creative processes. Take, for example, some of the risks that an urban process implies: social inequality, financing, safety and hygiene considerations and a broad range of other social, material and political uncertainties. Conventionally, local and national governments take on the responsibility of developing urban areas, sometimes with large commercial partners. But in the wake of the economic troubles of the last years, an increasing number of collaborative urban processes are taking place.. The question arises whether medium- and small-scale investors could be given responsibility over the collective interests of the communities they are acting within.

While during a City Game players find it easy to promise to take on such responsibilities and commitments, perhaps because of the contained, controlled and engaged environment created by the game, deviations from these agreements inevitably emerge in reality. The gaming environment could be perceived to be both too safe and too experimental in this respect. These commitments, once they jump out of the game and into reality, turn out to be difficult to pursue. The strengthening of some game rules, such as the veto, could help to overcome the discrepancies between the game and the reality. Such rules encourage critique and debate, including more stakeholders' perspectives of reality in the decision-making processes and their related commitments. The development of more rules that relate to the commitments players take on will influence reality by increasing the game implementation's feasibility and social sustainability.

15.4.3 Spatial Quality

The plural nature of City Gaming generated by bringing together experts, politicians, laymen and investors brings up the issue of whether the quality of the spatial outcome could ever reach the same level as one generated only by experts. Indeed, compared with a group of skillful designers, a disparate collection of players engaged in City Gaming will be less likely to generate formally coherent compositions. This issue is in part mitigated by the design of the games themselves, which lay out basic design parameters within which players can express their ideas about community, economy or other 'non-design' issues (rather than be challenged immediately with creating a spatial expression of their ideas). The method encourages players to bring their own individual interests and types of expertise to the table without being limited by relative capacities to design. Players then test these against the interests and expertise of others through discussions around alterations to an exiting plan. Due to the interests at stake and a limited amount of resources, players acting individually find it difficult to realize their own goals. Those lobbying and negotiating effectively tend to advance further in the City Game, mostly by modifying their original aims to fit a joint undertaking. The messiness and uncertainty of the play process could be perceived as a limitation for the method, yet it is the crucial factor that frees up participants to self-organize, as well as helping people to combine their skills in the process. It should be pointed out that similar negotiations do occur between designers, politicians and investors over building regulations, but they are often a side effect rather than the direct driver of change, as in the City Games. The designed drafts of urban plans and buildings generated by experts are also tested against imperfect and changeable social, political, environmental and economic agendas when they go on site, making their own leap from the table to reality. The directness and transparency a City Game provides might in fact be more desirable than the indirect negotiations a design proposal is subject to in current procedures, as it brings the direct 'imperfection' of the real site and its stakeholders into the planning process right from the start.

To some, and understandably so, the uncertainty of the outcome of City Gaming seems to be a serious handicap. For politicians, it is unsafe to involve such a process without knowing for certain whether the outcome will support their policies. Technocrats find it threatening not to know in advance whether unexpected turns in the play process might challenge existing rules and regulations. It is puzzling for many design professionals to accept that most urban processes are too complex to foresee. However, even when plans generated by traditional procedures create a sense of certainty, we know that the urban realities they function within are dynamic—changing so fast that by the time of their scheduled implementation many of these plans have been worn out, or outworn their relevance.

To work within (and, in time, transform) these cautious official structures, the gaming method requires courageous decision-makers who comprehend the added value of the play process to planning. City Gaming could be applied as part of existing planning processes or even replace them. It is a risky step for many, with few precedents (beyond our own experiments) of gaming being used to guide the implementation of urban processes: While 'serious gaming' has been widely used for indirect training, learning and strategizing within the field of urban planning, City Gaming aims to transform the practice of planning itself, and, to reach its full potential, needs innovative planners to let go of predetermining the future and take it up in their day to day discussion and production of the city.

15.5 Is City Gaming the Future of City-Making?

Since the first Generative City Gaming session held in 2008, I have set up and observed numerous City Gaming experiments and their outcomes. Based on these, I can conclude that the method can successfully serve a range of purposes: *simulating self-organizing urban mechanism*, as in Almere Haven; facilitating *collaborative design,* first achieved in Oude Westen; *conflict resolution* and *unlocking conversations*, as found in the exploration of Istanbul's urban transformation; *mapping city initiatives and ideas*, as in the Amsterdam Noord game; *testing urban plan rules*, as in the Oosterwold case, where the main premise of a master plan—here a set of rules geared towards coordinating the self-organization of a neighborhood—could be 'played out' in order to improve its guiding rules before implementation; and *temporary city planning, programming and building*, as in Van Gendthallen. While this research had a global goal of transferring gaming into a generative, and practicable, urban design process, in most of these experiments it was not possible to estimate the impact of the Generative City Game on the real case and site in advance. I can now conclude that the method has no fixed outcome, however much the initial game setup is designed. To activate a frozen master plan, for example, relies on the ideas and interactions the players bring to the table; a City Game's effectiveness is dependent on its stakeholders, whether they collectively decide to reactivate a frozen plan, co-create an alternative one or map their individual initiatives to lobby for change at the institutional scale. The one property that remains stable is that the outcome is a negotiated and thus based on consensus between engaged stakeholders. The result may be a plan, but can equally be a community who are aware of conflicts over a plan and the sensitivities of other participants—and thus better placed to build or challenge a plan.

The evolution of the City Gaming method can be observed throughout this research, with its most advanced state in its latest iteration; Play Van Gendthallen yielded an outcome that was built by the players in the three months following the game. The prospect of making collaborative City Games with the aim of involving players in implementing their outcomes is thus shown to be feasible. This successful case-study shows that play can become reality. The next step is creating a City Game system that can function across a range of scales, such as 1:30 building scale, 1:300 city block scale, 1:3000 neighborhood scale and 1:30.000 metropolitan scale, with this level of engagement and success. This kind of scalable City Game could create an interactive environment where collaborative dynamic visions, structure plans, initiatives and implementation plans could be interlinked, and tackled by the players through the gaming system. But what happens when the system implies jumping off the board game into such large scales of real production? Could a constant interactive process continue to run throughout, in a cyclical and open-ended way, from the proposal of players' abstract visions to the collaboratively realized projects? Can the concrete implementation phase of a project continue to benefit from the questioning and interaction that comes at the discussion stage around an abstract idea, even after it has gone 'on site'? Play the City have set out to answer this question with the next City Game—currently being set up in Cape Town—hoping to transform the method into one that is increasingly cyclical and inter-scalar.

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Chapter 16
Designing for Different Dynamics: The Search for a New Practice of Planning and Design in the Dutch Delta

Han Meyer and Steffen Nijhuis

Abstract The Dutch delta is an example of a complex urban landscape, the result of different processes with different time frames. Such an urban landscape can be regarded as the product of mutual relationships between natural processes and human interventions. Since the 1970s, landscape architects and urban designers have tried to conceptualize these mutual relations between different processes using a 'layer approach'—where substrate, infrastructures and land-use patterns are regarded as different urban layers with different speeds of change—based on the theories and methods of Braudel (La Mediterranee: La part du milieu. Colin, Paris, 1966) and McHarg (Design with Nature. Natural History Press, New York, 1969). The Dutch river and delta landscapes are an important laboratory for experimenting with new approaches which try to take into account the different dynamics of the different layers. The development of a 'framework model,' applied in the Dutch *Room for the River* program, a comprehensive spatial planning approach, is an initial attempt to create new relationships between the layers at the regional scale. It creates a balance between a clearly defined and designed framework, composed by natural elements and manmade infrastructures, and the possibility for local adaptations of urban and agricultural land use. However, as a long-term developmental strategy the framework should be adaptable to possible changes. The paper describes the attempt to develop a design approach for an adaptive framework in the Rotterdam region. Adaptive frameworks create the conditions for short-term societal changes as well as for long-term adaptation to possible changes of the natural substratum.

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16.1 Introduction

Urban regions can be considered to be complex systems, composed of different layers or subsystems such as the natural substratum, the infrastructure networks and land-use patterns (McLoughlin 1969; Meyer and Nijhuis 2013; Dammers et al. 2014a, b). Each of these subsystems can be characterized by its own dynamics and speed of change, although each layer will be influenced by changes in other layers. Throughout the twentieth century, designers, planners and engineers have tried to synchronize the dynamics of the different subsystems and integrate them into a single comprehensive planning approach. However, these attempts at creating a comprehensive system have often resulted in rigid spatial constructions, which are unable to deal with unexpected changes in any one layers and are therefore extremely vulnerable (Campanella 2014).

This paper addresses the question: How can we develop an approach to planning which can deliver flexible conditions for the different rhythms of change in the layers without resulting in total anarchy and the collapse of the system as a whole? We want focus on the role and content of *design* at the regional scale: In what sense can design play a role in the future development of urban regions, taking into account that these regions are extremely complex, with uncertain futures defined by many different processes with different dynamics?

The paper will focus on the Dutch urbanized delta landscape, which is an interesting model through which to discuss the need of a new approach in design and planning. In the next section, we will explain the complex relationship between the natural landscape and human interventions in general terms. We will then describe the attempts to develop a comprehensive approach to urban design, landscape design and spatial planning during the twentieth century, attempts which, in the Netherlands, resulted in a successful flood defense system and an economic leap forward. However, the following section of this paper argues that this system also produced problems which make the system vulnerable in the long term. The *Room for the River* program will be discussed as a first attempt to develop a more resilient and adaptive spatial planning approach, but one that needs further elaboration. The next section will discuss the introduction of scenarios and 'adaptive frameworks' as necessary tools in current and future spatial design and planning. We will end with some concluding remarks.

16.2 The Complex Relationship Between the Natural Landscape and Human Interventions

The Netherlands is the most densely populated country in Europe (almost 17 million people on about 40,000 km^2). In order to make its delta landscape habitable, a range of human interventions have transformed it over more than one thousand years. The

Dutch urbanized delta landscape can therefore be regarded a result of the action and interaction of both natural and human factors (Council of Europe 2000). The structured landscape is a mediator between nature and society, based on a material space created by man-made patterns combined with an ecological system (Zonneveld 1995; Burel and Baudry 2003). The urban delta comprises functions with spatial and temporal dimensions. Here the concept of the *longue durée* is crucial: understanding the landscape as a long-term structure which is changing slowly. The landscape is a system in which different processes and systems influence each other and have different dynamics of change. The first level of dynamics is related to the natural environment and is characterized by a slow, almost imperceptible, process of change, repetition and natural cycles. The second level of dynamics is related to the long-term social, economic and cultural history. The third level of dynamics is that of short-term events, related to people and politics (Braudel 1966). To better understand these dynamics and their impacts it is important to describe and classify them, in order to be able to compare them and find relationships between them (Nijhuis and Pouderoijen 2014). Important clues for the translation of this concept of mapping different systems in spatial design and planning can be found in Ian McHarg's influential book *Design with Nature* (1969). Here several types of landscapes are analyzed by distinguishing the different dynamics of the layers that make them up, such as the substratum, infrastructure networks and urban and agricultural land-use patterns. This layers approach was very influential in Dutch academic debate in the 1970s and 1980s, and became a leading approach in professional planning practices from the 1990s.

In order to identify key locations, critical driving forces and impacts of different dynamics, the spatial relationships between environmental conditions and human responses and interventions can be explored via cartographic research and mapping, employing analytical operations such as map dissection and map comparison. Map dissection decomposes the landscape into different layers, stratifying them according to the level of influence and dynamics of change. Map dissection is a useful tool for discovering spatial patterns by selection and reduction, and serves as the basis for spatial association analysis, which explores the relation between different patterns using a layered approach (Nijhuis and Pouderoijen 2014). Layers with a low dynamic of change are substratum and climate. These environmental conditions are regarded as the most influential conditions for land use, and are known as first tier conditions. Infrastructural networks for transportation, water management and energy supply are a second layer. They are also important conditional factors for land use, but their development and transformation goes faster than the environmental conditions and are therefore known as second tier conditions. Together, these conditions pave the way for the development of agricultural land use and urban settlements resulting in the layer with the highest dynamics of change and transformation (Nijhuis and Pouderoijen 2014). We identified similarities and dissimilarities in space, time and theme by comparing maps of the conditions and their results (Fig. 16.1).

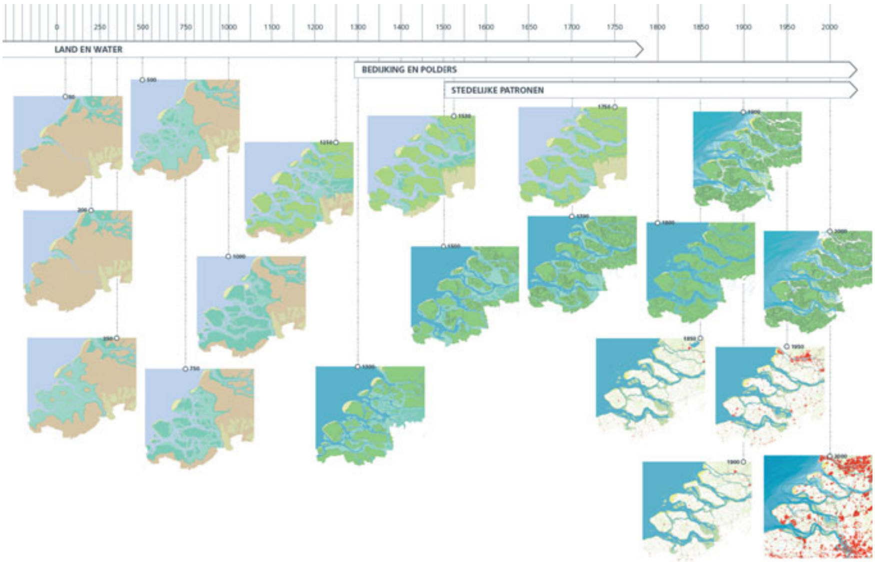

Fig. 16.1 The different dynamics of natural land-making, diking and polder-making, and urbanization in the Dutch Southwest delta (Maps by Nijhuis and Pouderoijen, TU Delft)

16.3 The Dutch Delta as a Showcase of Modernist Comprehensive Planning

During the nineteenth and twentieth centuries, the idea was established in the Netherlands that it would be possible to control the urbanization process of the delta landscape, and subject the landscape completely to the needs of human society. The idea of a comprehensive national policy concerning land-making, flood defense, urbanization, traffic planning, industrialization and agricultural policy was applied in practice with the construction of the '*Zuiderzee* works' and the 'Delta works' (Meyer 2009). The Zuiderzee works provided the closure of the *Zuiderzee* (South Sea) with a 32 km dam, the reclamation of approximately 2500 km^2 new land for agricultural use and the construction of a series of new towns (Fig. 16.2). The Delta works were constructed after a disastrous flood in 1953, which ruined a large part of the southwest delta and resulted in 1800 victims. The Delta works provided the closure of the river mouths with dams and storm surge barriers and the separation of the estuaries into freshwater or saltwater compartments (Fig. 16.3).

Indeed both 'grand projects' resulted in strong protection of almost the entire territory of the Netherlands against floods. The Dutch experienced an unprecedented long period of more than half a century without serious floods. Moreover, the *Zuiderzee* and Delta works contributed to a spectacular economic growth of the country (Don and Stolwijk 2003). The Zuiderzee reclamations created a large area

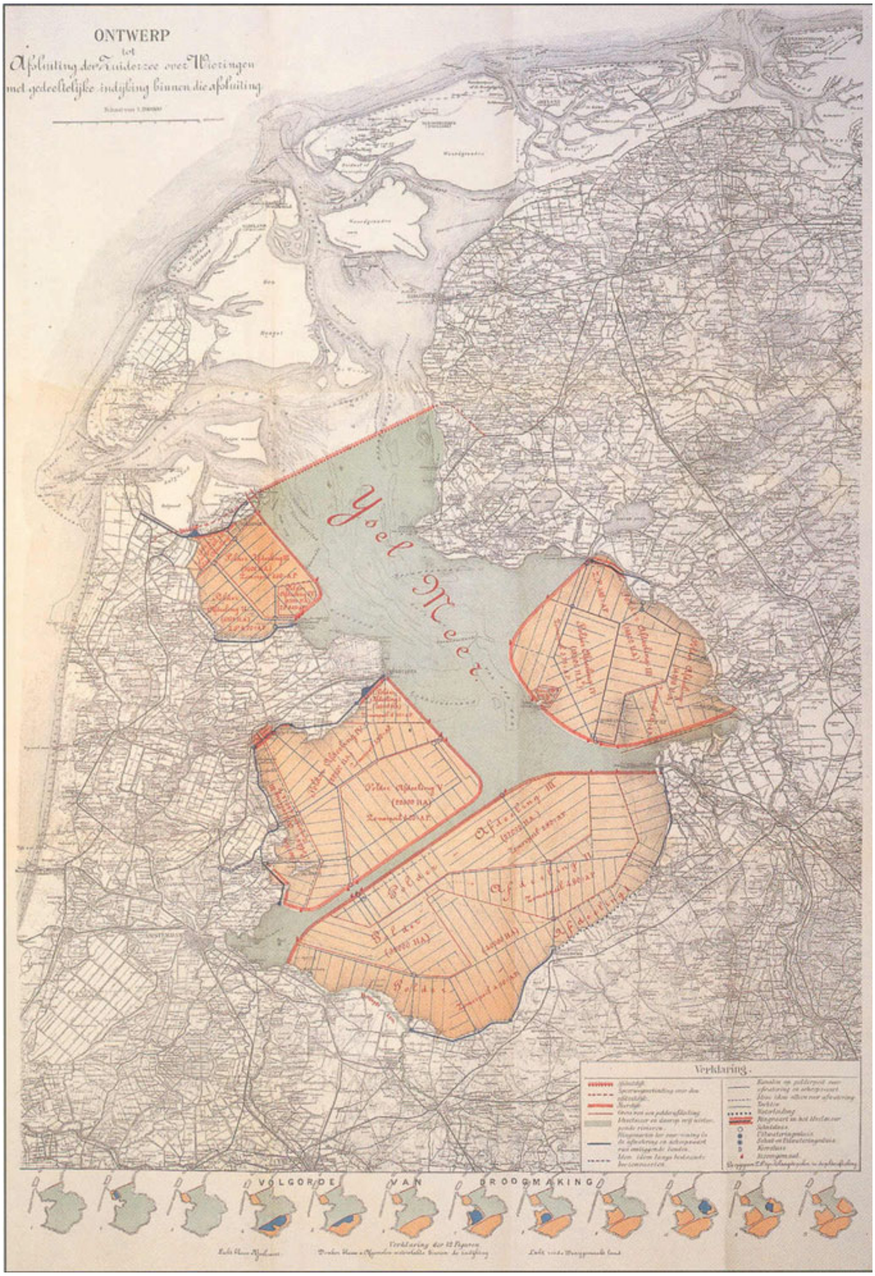

Fig. 16.2 Design for closing and reclamation of the *Zuiderzee*, 1891 (*Source* National Archive, The Hague)

Fig. 16.3 Plan for the Delta works, 1962 (*Source* Rijkswaterstaat)

of new, extremely fertile agricultural land: one of the most fertile and productive agricultural areas in the world (Berkhout and Terluin 2014). The Delta works' transformation of estuaries into fresh water compartments increased the productivity of national agriculture. Moreover, the Delta works were combined with increased accessibility of the southwest delta islands, which resulted in the growth of both the industrial and the tourism economy (Meyer et al. 2010).

Together with the national spatial planning documents of the 1960s and 1970s (Ministerie VRO 1966, 1974), the *Zuiderzee* and Delta works are considered the ultimate benchmark of a comprehensive planning policy in which all subsystems are synchronized. Both large-scale works contributed to the central aim of the 'Dutch Planning Doctrine' (Faludi and van der Valk 2010). The aim of this doctrine was avoiding too much concentration of urban and economic growth in the western part of the Netherlands and stimulating a more equally distributed pattern of urban and economic growth over the national territory. The *Zuiderzee* and Delta works played a crucial role in this strategy by improving the accessibility of the peripheral regions of the Netherlands. The new road networks on dikes and dams supported the growth of new urban and economic centers in the reclaimed polders and peripheral areas. The Second Memorandum on Spatial Planning (Ministerie VRO 1966) was an influential policy document that aimed to achieve equal distribution of urban and economic growth on the national territory (Fig. 16.4).

Fig. 16.4 Plan for the Netherlands in 2000, according to the 2nd Memorandum of Spatial Planning, 1966

Spatial planning and hydraulic engineering are both based on the assumption that it is possible to predict, plan or control the future of systems—as well the water system of rivers and coast as the system of land use for social and economic functions. However, both the river system and the economic and demographic developments moved in directions different to what policymakers anticipated: Climate change, deforestation in upstream areas and river canalizations resulted in larger water discharge quantities than expected. During the 1990s, there were nearly two flood disasters in the Dutch river area (Klijn et al. 2012). A Delta committee, installed by the government, concluded that the flood defense system was not prepared for future river discharges and sea level rise, and should be updated. Moreover, climate change compelled the committee to revise the whole flood defense system fundamentally (Delta-committee 2008). Demographic and economic developments also moved in a different direction than foreseen. The spatial planning policy of the 1960s was based on a prediction of 20 million inhabitants in the year 2000 (Ministry VRO 1966). However, the Dutch population reached barely 16 million in that year. At the same time, the gross domestic product in the year 2000 was six times greater than expected in the 1960s (Don and Stolwijk 2003).

Aside from the consideration that it is not possible to predict and plan the future exactly, the neoliberal idea that the market should take a leading role became dominant in Dutch policies. As a result of both developments, central government decided to stop national spatial planning (Roodbol-Mekkes et al. 2012). The national government is now only responsible for large-scale infrastructure systems for transport and flood defense (Ministerie I&M 2012).

The need to update the country's flood defense system became subject of a political debate because of the increasing public support for nature reserves and environmental planning. This resulted in pressure to combine flood defense strategies with attention to the natural environment. Spatial development in the river delta and coastal areas faced the question of how two new developments could be combined: how can urban, landscape and agricultural development—which is no longer considered a case of national interest, and which should be developed with a more market-oriented and 'bottom-up' approach related to local and market forces—be combined with a new approach to water management, which still is regarded as a matter of national interest and which should pay more attention to 'working together with water'?

16.4 First Steps Towards a New Planning Approach: A Robust Frameworks with 'Simple Rules'

From the 1970s onwards, the 'layer approach' and its theoretical backgrounds became increasingly influential in Dutch design and planning experiments. Young landscape architects took up the idea of developing spatial frameworks which can be regarded as systems of natural and man-made structures such as rivers, roads and forests, which are sustainable in the long-term and include several types of land-use (Sijmons and Venema 1998; Sijmons 2002). This concept of designing strong frameworks for sustainable landscape development resulted in a regional design approach that employed a ‘framework-model’ (*Casco-concept* in Dutch). An important basic premise of this model is to deal with time, uncertainty and (shifting) responsibilities based on the physiology of the landscape. The framework model strives to create a pattern of interconnected zones in which long-term, sustainable conditions for ‘low dynamic functions’ (such as nature reserves) are provided, as well as envelopes: expanses of land in which dynamic functions, such as urbanization, recreation and agriculture, can flourish. The model was developed as an important planning and design strategy in the Netherlands from the late 1980s onwards, with Kerkstra and Vrijlandt (1990, 1991) and Sijmons (1991) as key proponents.

The first application of the framework model was in a winning competition entry for a regional landscape design called “Plan Stork” (*Plan Ooievaar* in Dutch) focusing on the area around the Rhine and Meuse rivers in the center of the Netherlands (De Bruin et al. 1987, Fig. 16.5). The plan proposed a new structure for the area which would enhance and reinforce agricultural land-use in the former flood basins, mixed land-use on the natural levee deposits and nature development in the newly established riparian zones.

In 2005 the national program “Room for the River” (*Ruimte voor de Rivier* in Dutch) started (Ministerie VROM 2004, Kwaliteitsteam Ruimte voor de Rivier 2012). It is an important case study for a new approach to planning and design in the complex conditions of the delta landscape. In the mid-1990s, two serious high-water situations in the river-area reinforced the idea that the era of controlling nature was over. Experts felt that these floods were evidence of a fundamental change in the behavior of the two rivers as a result of climate change (Klijn et al. 2012). This conviction, taken up by Dutch planning-institutions, was behind the search for a new approach to spatial planning and hydraulic engineering.

The increased concern with the environment as well as with the effects of climate change resulted in the national planning policy project *Room for the River* (Kwaliteitsteam Ruimte voor de Rivier 2012), to be implemented in the period 2005–

Fig. 16.5 *Plan Ooievaar*, plan for the river area near the cities Arnhem (*top right*) and Nijmegen (*bottom right*), 1987 (Image courtesy of Dirk Sijmons)

2015 (Fig. 16.6). This program focuses on the river landscapes of the central and eastern Netherlands, where a series of canalization projects and towns are bottlenecks —spots at risk of flooding—in periods of extreme river discharges. The need to expand the river system's capacity is urgent: While the existing river system was able to deal with extreme discharges of 12,000 m^3/s, climate experts calculated that by 2050 the two rivers could discharges up to 16,000 m^3 a second. The canalization of the rivers also resulted in the destruction of the biodiverse ecosystem of the river landscape. The *Room for the River* program included design studies for 38 project areas, and sought to combine the creation of more space for the discharge and temporary storage of the river water with the repair of river landscape features. The policy and these projects are a new approach to working with nature in planning.

The groundbreaking integral design of *Plan Stork* is the foundation for the *Room for the River* program. In both, subsoil and infrastructural networks (e.g. dikes, roads) are the constituent elements for planning and the design of frameworks. Taken together and following a set of simple rules, these create conditions for the sustainable development of urban and agricultural land use (Sijmons 2012). The simple rules used in the plan created flexibility for specific local solutions while setting clear limitations. The framework and its guiding rules enabled national and local stakeholders to develop spatial designs jointly focusing on the conditions specific to the site, but guided by the general goals of the program.

The *Room for the River* program's attention to the different dynamics of the natural environment, climate change, urban development and infrastructural

Fig. 16.6 Map of room for the Rivers program, indicating 39 projects for widening the river bed or creating by-passes (Image courtesy of Kwaliteitsteam Ruimte voor de Rivier 2012)

systems made it an important innovation in the Dutch approach to planning and design. The approach created the conditions for a combination of precautions against flooding with attention to a sustainable natural environment and, at the same time, enabling a more liberal (or ‘self-organizing’) urban development. For this reason, the model was considered to be the ideal example of two government policies emphasized at the start of the twenty-first century: it represented both the ‘working with water’ approach and the plea to abolish spatial planning at the national level while paying more attention to ‘bottom-up’ practices.

Though successful, the *Room for the River* program has some limitations for application in urban areas. First, the combination of hydraulic engineering, landscape architecture and environmental design were relatively easy in the *Room for the River* program, because of the relatively simple societal context of these rural areas. Farmer’s protests could be taken into account relatively easy, and resolved by making changes to the original designs. An important question is how a comparable balance between a framework of river systems and urban development can be achieved in a complex metropolitan area such as the Rotterdam region.

Second, the implementation of the program and all related projects had a clear, strict time frame (one decade, from 2005 to 2015) and a strict budget. Developments after 2015 are not included in the program; it is not clear in what sense new developments in climate change and river discharges after 2015, or new initiatives for real estate or nature development after 2015, can be included in the *Room for the River* framework. For instance, the program is based on the prediction that, due to climate change, river discharges will increase to 16,000 m^3/s by 2050. However, more recent calculations show that they could increase to 18,000 m^3/s or even more by, or after, 2050 (Klijn et al. 2012). This means that the framework of dikes and river beds created by the program should be adaptable after 2015 in order to be effective. However, possible future changes and adaptations are not included in the spatial framework.

In order to deal with the fundamental uncertainty concerning long-term future spatial development—created by the uncertainty inherent in climate change and the complexity of metropolitan regions—further elaboration of the framework model of *Room for the River* is necessary: the framework itself needs to be designed to be adaptable.

16.5 The Next Step: Adaptive Frameworks—Planning with Time, Uncertainty and Shifting Responsibilities

The Rotterdam region can be regarded as an interesting laboratory for the development of a next step in spatial planning and design. In this region, one of the most urgent long-term and large scale questions that needs to be addressed in the coming fifty years is whether the *Nieuwe Waterweg* (New Waterway) should remain the main discharge channel of the rivers Rhine and Meuse. The *Nieuwe Waterweg* is an artificial mouth of the rivers Rhine and Meuse, dug in the nineteenth century to provide a better discharge-flow for the rivers and to improve the accessibility of the Port of Rotterdam for sea vessels (van de Ven 2008). But the *Nieuwe Waterweg* is increasingly causing problems. The rising sea level influences the water levels in the artificial river mouth, leading to an increasing flood-risk for the urban areas alongside the *Nieuwe Waterweg* and increasing salinization of the groundwater in the region (Meyer et al. 2012). Both changes raise the question of whether this artificial river mouth can be maintained in the long term. But changes to the *Nieuwe Waterweg* would conflict with the interests of the port, whose functioning requires continuous accessibility. However, the Port of Rotterdam is growing towards the west and will face substantial reorganization because of energy-transition (Port of Rotterdam 2012); the port authorities' argument that this waterway must stay open could lose its significance in the future.

The alternative would be that the river mouth branch *Haringvliet* (in the south of the region) would acquire the role of main discharge channel of the Rhine and Meuse rivers (Fig. 16.7). This choice would have serious consequences for all systems: affecting the type of flood defense systems that could be constructed alongside the *Nieuwe Waterweg* and *Haringvliet*, for the functioning of the port of Rotterdam, and for the possibilities for new urban patterns along the waterfronts of both branches (Meyer et al. 2014).

To tackle these issues, we elaborated a method for adaptive design for the Rotterdam region. The result is a proposal for the introduction of a *Robust Adaptive Framework* as a strategy for the spatial planning and design of the Dutch delta (Meyer et al. 2014, 2015). It can be regarded as an elaboration of the framework model addressing issues of time, uncertainty and shifting responsibilities. The goal of the design process was to define a spatial framework which would be robust and adaptive both with regards to flood defense, climate change and sea level rise, as well as

Fig. 16.7 The three main river mouths of the rivers Rhine and Meuse in the Southwest delta. Top: *Nieuwe Maas* and *Nieuwe Waterweg*; Middle: *Oude Maas*; Bottom: *Hollandsch Diep* and *Haringvliet* (Map by MUST Urbanists)

environmental qualities, the port economy and urban development. Key locations, critical driving forces and predicted impacts formed the basis for the development of the *Robust Adaptive Framework* for the Rotterdam region. The framework was based on the understanding of landscape development through time (retrospective or historic design research), an inventory of current initiatives, the exploration of probable future developments (scenario studies by research-by-design) and the forecasting of shifting responsibilities (governance studies).

Historic design research was executed by mapping different historic phases, and resulted in important discoveries. One of these discoveries was influence of the mutual relationship between natural processes and human interventions on the composition of the delta landscape and the position of towns. It began with the natural process of sediment transport and silting up, which produced sand plates. The first human intervention was the construction of dikes to protect these plates against flooding. Ongoing silting-up processes created new dry land outside the first generation of dikes. This new land became part of the earlier polder island when people surrounded it with a second generation of dikes. This process was repeated several times, resulting in the growth of the island, characterized by a landscape with multiple dikes of different generations. The islands are surrounded by the most recent dikes, which are now the primary flood defense. Older dikes, currently playing a role as secondary dikes and tertiary dikes, run more or less parallel to the primary dikes. This process meant that most of the towns, originally port towns established at the edge of the islands, were increasingly separated from the water each time new land and new dikes were created. The towns tried to keep their connection with the water by digging canals through the new land and constructing sluices in the new dikes (Fig. 16.8).

The inventorying of current land-use initiatives showed that most new initiatives are concentrated in the zones between the primary and secondary dikes. Municipal authorities try to repair the link between their town and the open water by stimulating new real estate projects, nature development and marinas in these zones. Meanwhile, environmental organizations emphasize the importance of redeveloping these zones to create transition zones between water and land in order to repair the natural estuarine conditions. The National Water Management Agency and regional water boards, however, want to reserve these zones for any dike enforcements that may be needed in the future. All these conflicting initiatives compete for the zones in-between the outer dikes.

To explore the probable future development of the Dutch Delta, scenario studies combined realism with imagination to pinpoint critical key locations, the driving forces and the potential impact (both opportunities and threats) of events in the future (Fig. 16.9). Scenario-study is a helpful tool for dealing with uncertainty and generating knowledge on trends and their mutual relations, new problems and challenges and policies and their impacts, as well structuring strategic conversation and stimulating participation (Dammers et al. 2013; Veeneklaas and Van den Berg 1994; Lindgren and Bandhold 2009). Building scenarios implies the formulation of an internally consistent and coherent set of assumptions about the main relations under study. Based on this consistent set of assumptions, a systematic but selective description of the current situation can be made and the most important external

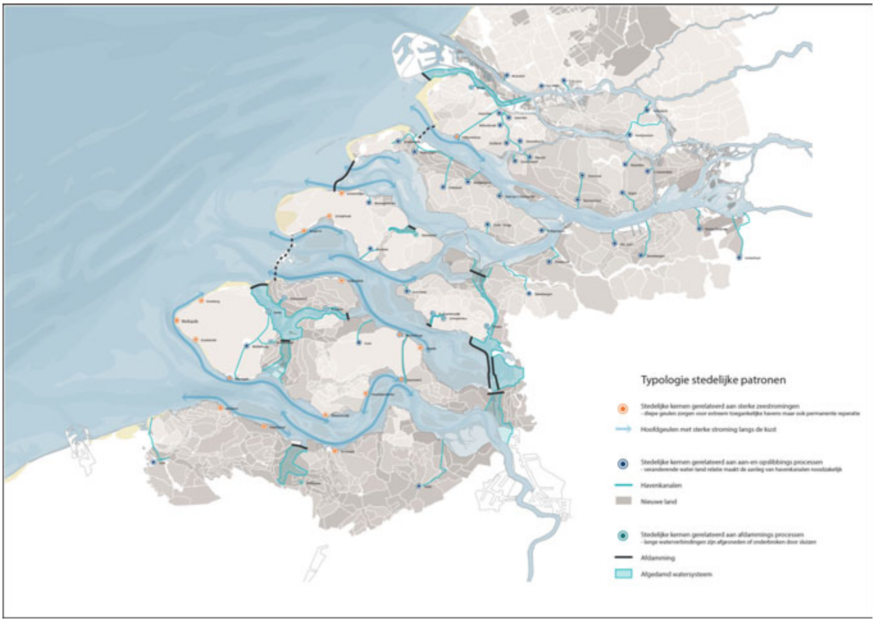

Fig. 16.8 The landscape of the Southwest delta: polders, dikes, towns and canals connecting the towns with the estuaries (Map by Nijhuis, Pouderoijen, and Warmerdam, TU Delft)

factors that determine the course of the spatial development identified (Veeneklaas and Van den Berg 1994).

Together, the analysis of the development of the landscape through time, the analysis of current initiatives for spatial developments in the region and pinpointing the most important factors for future development, identified the zones between primary and secondary dikes as crucial for future development. The fourth part of the analysis was focused on the question of whether it is possible to create conditions for new governance arrangements: speculating whether different stakeholders would be able to find ways of collaborating, agreeing on a design and fine-tuning it. Interviews and workshops with stakeholders were organized to investigate possible agreements between them. During the workshops stakeholders were brought together around digital map-tables, on which the relationships between different systems could be shown. Participants were able to see the possible consequences of their initiatives on other systems and stakeholders immediately. This digitalized mapping system, called the *Delta Envisioning Support System* (Fig. 16.10) (Dammers et al. 2014a, b) speed up the discussion on different proposals with all stakeholders and formed the basis for the design of the *Robust Adaptive Framework* for the Rotterdam region.

The proposed framework delivers conditions for adaptation to long term changes in water levels and river discharges, as well as for short term changes in land use for environmental, agricultural or real estate purposes. In rural areas, the zones between

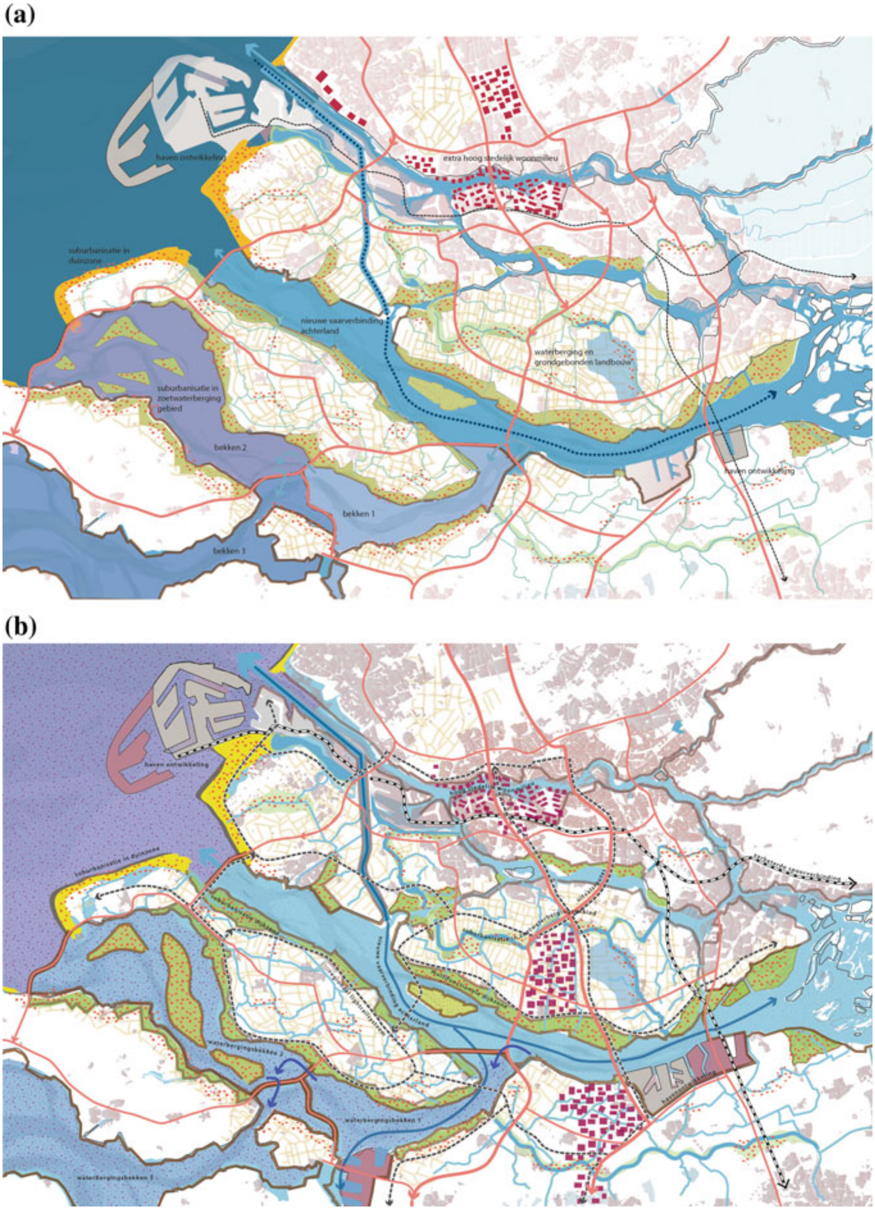

Fig. 16.9 **a** Scenario 'Rest' for the Rotterdam region: exploring a future with a minimal climate change and a minimal economic and demographic growth (Map by H + N + S Landscape Architects). **b** Scenario 'Steam' for the Rotterdam region: exploring a future with an extreme climate change and an extreme economic and demographic growth (Map by H + N + S Landscape Architects)

Fig. 16.10 Research-by-design, working with map-tables in DENVIS ('Delta envisioning support system'), IPDD project June 2013 (Photo by Roy Lazet)

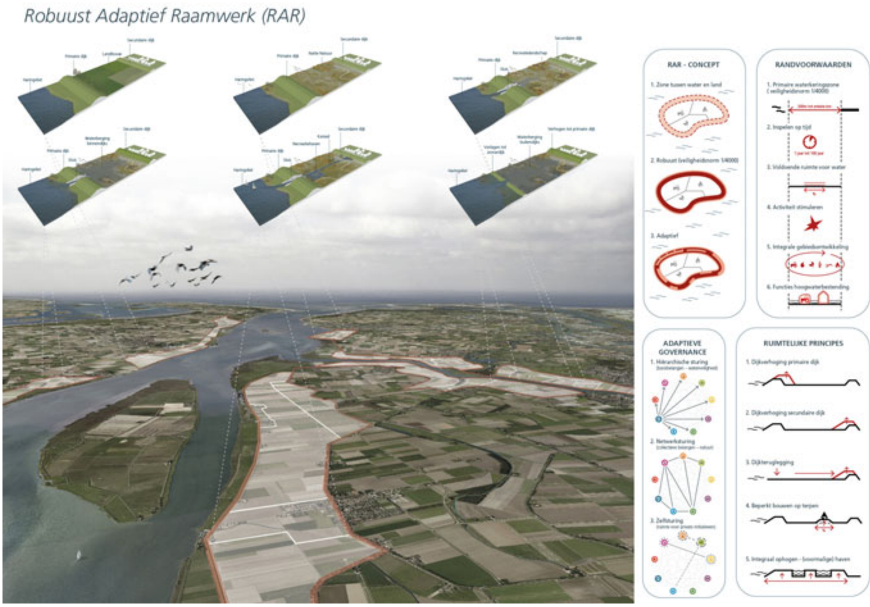

Fig. 16.11 Proposal for a *Robust Adaptive Framework* for the *Haringvliet* embankments, IPDD project (*Source* Meyer et al. 2014, 2015)

the primary dikes and the historic secondary dikes should also be regarded as part of the robust flood defense system. These areas can be used for nature, agriculture or small-scale residential projects, as well as for water storage in times of extreme discharges. In the urbanized and industrialized area of Rotterdam and its port, the elevated outer-dike areas are part of the framework. They can be considered part of a robust flood defense system that protects the hinterland and can be adapted to changing water conditions in the future. Figure 16.11 shows a part of the framework: the zone alongside the *Haringvliet* branch, between the primary and secondary dike, and the sections showing different future possibilities for combinations of flood-defense and land-use in the future. Figure 16.12 shows a possible future situation of this zone, based on explorations of one of the TU Delft students.

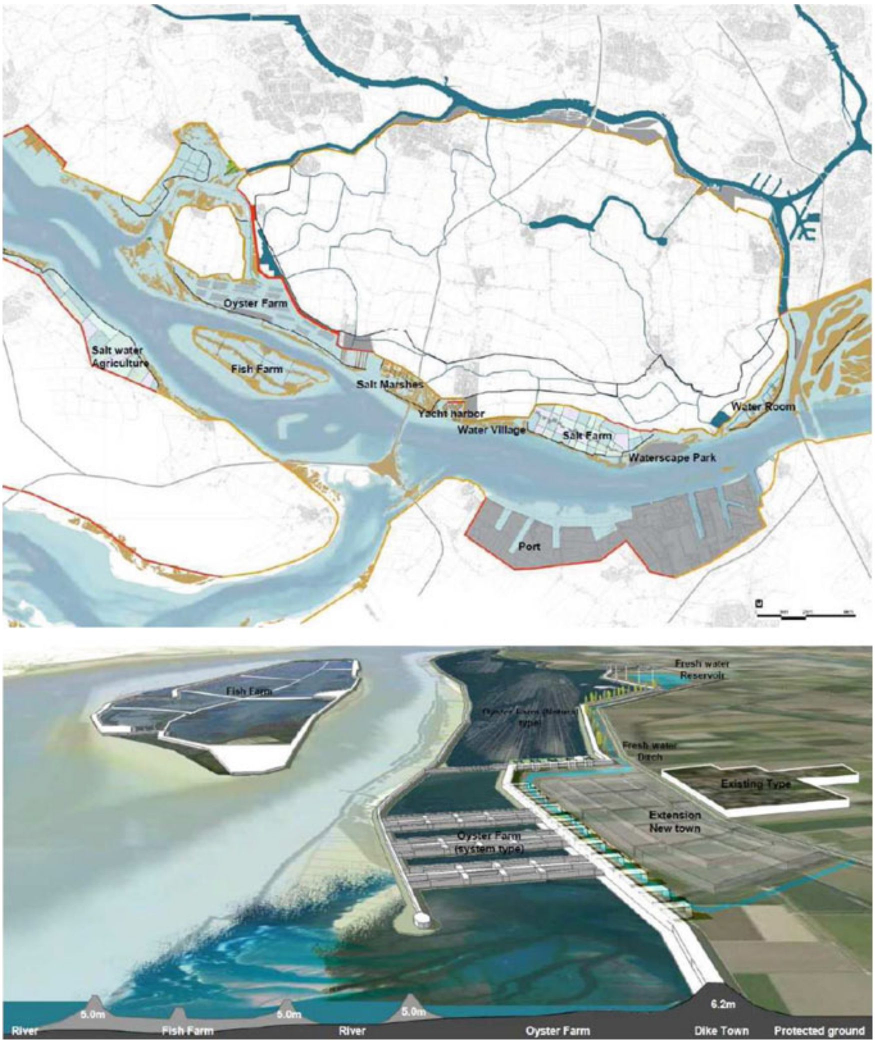

Fig. 16.12 Exploring the spatial possibilities of the *Robust Adaptive Framework* implementing oyster and fish farms (Design by Joon Kim, EMU studio TU Delft 2011)

16.6 Concluding Remarks

It is important to be aware that landscape and urban design in these complex environments cannot be focused on the realization of one final image. We have to take into account that we should create conditions for different processes which are characterized by different time frames and different levels of uncertainty. Design plays an important role as a method of exploring how different processes with different time frames can be combined in one plan. There is not a single approach for making urbanized deltas more sustainable, resilient and adaptive yet; we are still in a process of experimenting, searching and finding.

The need to renew the water management and flood defense system can function as the engine to reconfigure the urban structures, environmental systems and economic structures that make the metropolitan region of Rotterdam. This process might also contribute to the development of a new balance between central state responsibilities, local or regional authorities, NGOs and private citizens, made possible by the introduction of plans like the *Robust Adaptive Framework*. The essence of such a framework is that is can build upon historic patterns and creates possibilities for collective action by different actors. Design research (the analysis of previous designs and patterns) and research-by-design (testing different possibilities for an area) both play an important role in this approach.

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