Cities 73 (2018) 91–95

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Why plans matter for cities

Shih-Kung Lai

College of Architecture and Urban Planning, Tongji University, Shanghai, China

A R T I C L E I N F O

Keywords:
Plans
Complexity
Network science
Four I's
Urban development

A B S T R A C T

That plans work in urban development is a claim that lacks theoretical and empirical backing. In the present paper, we consider the urban development process as a set of five partially independent streams of problems, solutions, decision makers, locations, and decision situations. When the elements of the five streams collide under some structural constraints and fulfill an energy surplus decision rule, decisions are made. Given this model of urban development in which plans and the planner are embedded, we prove axiomatically that some characteristics of urban development decisions, namely interdependence, indivisibility, irreversibility, and imperfect foresight, or the four I's, are the sufficient condition for the complexity of the city, and that the four I's in turn are the necessary condition for why plans work. The two lemmas together give rise to the theorem that plans work in the face of complexity as manifested by the urban development process. The theorem reached from the axiomatic system provides a theoretical basis on which planning is practiced in the face of complexity and the results might prompt us to return to and focus on plans as the object in planning research.

1. Introduction

We plan for our daily life: when and where to work, shop, play, eat, drink, meet, rest, and etc. In the context of urban planning, we plan for urban development through agenda, vision, design, policy, and strategy (Hopkins, 2001).Though planning is a ubiquitous phenomenon, little has been said about why plans emerge and when plans matter partly because traditionally we view cities as simple and linear systems which tend toward equilibrium (c. f., Byrne, 2003). Planning in such a world is straightforward in effects which are embedded in a set of linear causal links. We now know that cities are complex and nonlinear of which the urban development process is non-equilibrium (e. g., Alfasi & Portugali, 2007; Batty, 2014; Byrne, 2003; Moroni, 2015; Portugali, 2008; Rauws & De Roo, 2016; Yamu, De Roo, & Frankhauser, 2016). More specifically, Byrne (2003) argued for complexity approach to planning as synthesis across knowledge and action, rather than positivist's or postmodernist's approach as extremes. Alfasi and Portugali (2007) proposed a planning system that intends to bridge the separation between planning theory and built environment. Using paradoxes in science, Portugali (2008) listed major planning paradoxes and explained how they came about through the conception of self-organization. Moroni (2015) argued forcefully how we should design planning regulations that adopt the conception of self-organization to cope with urban uncertainties. Yamu et al. (2016) and Rauws and De Roo (2016) identified, both descriptively and normatively as well as theoretically and empirically, the conditions for urban development that view cities as complex adaptive systems and proposed the conception of adaptive planning. The relevant literature is large, but it would be safe to argue that all urban complexity theorists conceive cities as complex adaptive systems that defy traditional linear approaches to dealing with uncertainties and that most such discussions are confined to conceptual debates without concrete operational meanings. Regardless, planning effects in such a world is still ambiguous at best and the nonlinear causal links are hard to pin down.

Imagine a simple world where decisions are independent of each other. There is no need for plans in such a situation because each decision can be considered separately without being referred to other decisions. This is our presumption of the traditional way of problem solving for cities. Thus, housing problems can be tackled ignoring land use and transportation issues. However, most, if not all, urban development decisions are interdependent (Hopkins, 2001) in that solving one problem would cause consequences on others (Rittel & Webber, 1973). It is not surprising that planners view these unexpected consequences as planning disasters (Hall, 1980). What planners do not know is that these disasters come about mainly because of the complexity of the urban development process. As a result, we need to look at cities afresh by considering them as organisms rather than machines (Batty, 2014). This shift in perspective about cities has a significant impact on how we should think about plans. For example, plans and the city are not separate entities; rather, they co-evolve. Plans emerge endogenously from the complex urban system under consideration, rather than being imposed exogenously from outside; therefore, there exists a

E-mail address: lai@tongji.edu.cn.

http://dx.doi.org/10.1016/j.cities.2017.10.014
Received 21 May 2017; Received in revised form 17 September 2017; Accepted 22 October 2017
Available online 06 November 2017

web of plans, rather than a single plan for urban development (Hopkins, 2014). Put differently, the planner as the observer of the city must be embedded in the system, rather than as an external experimenter who attempts to control the city (c.f., Prigogine & Stengers, 1984). All these new insights derived from the new perspective about the city require us to reconsider why plans matter in a complex urban development.

The present paper provides an axiomatic approach to this question of why plans matter in the face of complexity. The central conception concentrates on interdependence, irreversibility, indivisibility, and imperfect foresight, or the four I's that characterize the urban development process (Hopkins, 2001). Cities are no doubt complex systems which are mainly characterized by irreversibility (Nicolis & Prigogine, 1989), but cities are also characterized by agents, mostly humans, who are capable of strategic, adaptive behaviors. In particular, we will prove analytically that the four I's are the sufficient condition of why the urban development process is complex. We then prove deductively that the four I's are the necessary condition under which plans work. Drawing on the two lemmas, we can conclude that plans work in a complex setting; that is, plans matter in a complex system, such as the city. To simplify, throughout the proving process, we consider the city as a set of partially interacting decisions forming a network and a plan is defined here as a set of interdependent decisions. In Section 2, we depict a conceptual model of the city based on which the ensuing proofs are carried out. In Section 3, we set out by introducing some preliminary ideas. In Section 4, we proceed to prove the lemmas and theorem. In Section 5, we discuss some related issues. We conclude in Section 6.

2. The model of urban development

The model of urban development based on which the ensuing proofs are developed is called the spatial garbage can model, or SGCM (Lai, 2006), which has been partially validated empirically (Lai, Kuo, and Yu, forthcoming). The SGCM is an extension of the garbage can model, or GCM, originally proposed by Cohen, March, and Olsen (1972) by adding a spatial element of locations. The GCM is an attempt to capture the essential interacting elements of a complex organizational system by expositing four streams of partially independent streams: problems, decision makers, solutions, and decision situations (or choice opportunities). These four streams of elements meet in a random fashion subject to some structural constraints and if the elements of the three streams of problems, decision makers, and solutions collide in a particular decision situation at a particular time, then decisions may or may not be made, depending on whether the “energy” supplied by the colliding elements exceeds that demanded. In the SGCM, a fifth stream of locations is incorporated into the model in that if problems, decision makers, solutions, and locations each collide in a particular decision situation at a particular time, subject to some structural constraints and the decision rule of positive energy surplus, then decisions may or may not be made. The SGCM view of the city is distinct from that of the traditional urban modeling approach. In a sense, the SGCM view is to look at the city from inside, rather than from outside as perceived by the traditional urban modeling approach and most, if not all, complexity theory-based modeling approaches (e. g., Batty, 2005).

Based on the SGCM, the building blocks of the city are interacting decision situations, or decisions for short. There are numerous such decision situations forming a giant network. The physical environment of the city, such as roads, housing units, infrastructure, and public facilities, is embedded in these decision situations as locations. The structural constraints which confine where activities take place and who are involved, specify the relationships between problems and decisions situations (access structure), solutions and decision situations (solution structure), decision makers and decision situations (decision structure), as well as decision situations and locations (spatial structure). These structural constraints can roughly be considered as institutions. The city perceived this way is a giant, dynamic network of decisions interacting with each other, so that order as manifested by spatial or institutional structures emerges from chaos of seemingly random interaction. The reader is encouraged to consult Lai (2006) for the detailed workings of the SGCM.

3. Preliminaries

Based on the model of urban development as a set of interacting decisions, the following definitions of the relations between the decisions are given.

Definition 1. Dependence relation D

Let x and y belong to a non-empty set of decisions X. x and y are dependently connected, denoted as xDy or $(x, y)\in D$, if and only if the choice in x depends on the consequences resulting from the choice in y, but not vice versa.

Spatially, that the development along a river on a site upstream affects that on another downstream, but not vice versa, shows a dependent relation between the two development decisions. Temporally, that the development on a site early in the development of a human settlement affects the ensuing development, but not vice versa, demonstrates a path dependent relation between the two decisions of development in time. Mathematically, we can define the following relations based on the fundamental relation of dependence.

Dependent relation D:

$(x, y)\in D \bigwedge (y, x)\notin D$.

Converse of dependent relation $\overline{D}$.

$(y, x)\in D \bigwedge (x, y)\notin D$.

Interdependent relation I:

$(x, y)\in D \bigwedge (y, x)\in D$.

Independent relation N:

$(x, y)\notin D \bigwedge (y, x)\notin D$.

In addition, any two decisions are strongly connected if and only if their relation belongs to D, $\overline{D}$, or I. That is,

Definition 2. Strong connectedness

Let x and y belong to a non-empty set of decisions X. x is strongly connected with y, denoted as (x, y) or $(y, x)\in R$, if and only if (x, y) or $(y, x) \in D$, $\overline{D}$, or I.

It is arguably true that the relation between any two decisions in the urban development process falls into one of the four categories which can also be described in game theory (Hopkins, 2001).

In the context of the SGCM as depicted earlier, we assume that if two decisions are strongly connected, then they may have common problems, decision makers, solutions, or locations that could be attached to them. In other words, if two decisions are strongly connected, then they may be competing for problems, decision makers, solutions, or locations. The results of such competition of one decision will cause different consequences that in turn would affect the choices in the other decision. Consider the locational choices of a highway corridor and a shopping mall, both competing for locations with good accessibility. The locational choice of either decision would result in consequences that would affect the choice of the other. Therefore, they are interdependent and thus strongly connected. The same logic applies to the competition for problems, decision makers, and solutions.

In a complex network of decisions such as the city, decisions may be clustered, forming substructures of the system. In the societal context, for example, these clustered sets of decisions can be families, firms, governments, voluntary groups, or any other type of organizations.

Definition 3. Clustered set

Let C_i be a clustered set, $i = 1, 2, \ldots, n$. For any decision $x \in C_i$, there exists a decision $y\in C_i$ so that x is strongly connected to y.

The strong connectedness relation is defined on pairs of decisions. Clustered sets can also be weakly connected as defined below.

Definition 4. Weak connectedness

Let $C_i \cap C_j = \phi$, $i, j = 1, 2, \ldots, n$, $i \neq j$. C_i and C_j are weakly connected if and only if $\exists\, x_i \in C_i$ and $\exists\, x_j \in C_j$ so that x_i and x_j are strongly connected.

Indivisibility and irreversibility are related to the notion of increasing returns and path dependence, respectively (Arthur, 1994). In particular, increasing returns are a special, continuous case of indivisibility which results from agglomeration economy, while path dependence implies irreversibility. Both indivisibility and irreversibility together imply a clustered set of decisions which are *completely* strongly connected. That is, each decision in the set is strongly connected to every other decision in the set. Otherwise, the disconnected, independent decisions are divisible and reversible. Consider the construction of a road or building. Indivisibility implies that the construction decision must be made in a lumpy fashion. We cannot just build a segment of the road or a partial unit of the building; they must be constructed in a scale that meets the demand. We cannot select the corridor or location for the road or building and later move them to other corridor or location without additional costs. Thus, the elements of the road or building must be connected in making the construction decision. To simplify and without loss of generality, we set aside the case where irreversibility results from chains or subsets of strongly connected decisions in the clustered set. That is, we only consider the lumpy case. Therefore, we have.

Definition 5. Indivisibility and irreversibility

C_i is indivisible and irreversible if and only if $\forall\, x_j, x_k \in C_i$, $j \neq k$, so that x_j and x_k are strongly connected.

The definition of imperfect foresight is defined here to simply mean that whether a decision is realized is probabilistic. That is, decision situations are stochastic and may or may not occur. In addition, once a decision situation comes to existence, choices in it are made with uncertain consequences. All such uncertainties are assumed to be captured by the probability p under which the decision situation comes about. Let P denote a probability function and we have.

Definition 6. Imperfect foresight

$\forall x \in X$, a network of decisions. x is imperfectly foresighted if and only if $0 < P(x) < 1$.

Other definitions which are needed for the ensuing proofs and straightforward are given as follows. Note that a network is a topological set of decision nodes with given relations (arcs) between these nodes.

Definition 7. Disconnected network

$\forall x, y \in X$, (x, y) and $(y, x) \notin R$.

Definition 8. Ordered network

$\forall C_i$, $i = 1, 2, \ldots, n$, span the network. Let $x, y \in C_i$ and $x \neq y$. $(x, y) \in R$.

Definition 9. Random network

For C_i in the network, $\exists\, x, y \in C_i$ and $x \neq y$. $(x, y) \notin R$.

Definition 10. Complex network

A complex network is neither an ordered nor a random network.

It can be derived from Definitions 7 through 10 that in a complex network there exists at least a completely connected set and a disconnected set. Given the structural definition of complex network, we define, in the context of the SGCM, plans as follows:

Definition 11. Plans

Given a network of decisions, a plan is an assignment of problems, decision makers, solutions, and locations to strongly connected decisions in order to yield the maximum expected utility for the planner.

In other words, a plan is a set of interdependent decisions, a contingent path in a decision tree (Hopkins, 2001) and making plans is equivalent to making multiple, linked decisions (Han & Lai, 2011, 2012).

4. The theorem

Given the structural definitions of complex network in Definition 10, we now proceed to prove that interdependence, irreversibility, indivisibility, and imperfect foresight together give rise to complexity and that plans work in such complex network systems. To simplify but without loss of generality, we assume that the number of decisions in the network X is n, that is $|X| = n$, and that the total number of links of connected decisions in the network is fixed. Since the number of links reaches the maximum nk in the case of ordered network, where k denotes one half of the number of the decisions in a clustered set of an ordered network, we have $|R| = nk$ for the network. Assume further that a problem or solution can be associated with only one decision. Lemma 1 shows that interdependence, indivisibility, and irreversibility, under the condition of imperfect foresight, constitute the sufficient condition for complex systems.

Lemma 1. *Interdependence, indivisibility, and irreversibility together, under the condition of imperfect foresight, are the sufficient condition for complexity.*

Proof:

The strategy of the proof includes three parts. Firstly, we prove that weak connectedness implies the impossibility of an ordered network. Secondly, we prove that indivisibility and irreversibility imply the impossibility of a random network. Finally, with the two parts given, we conclude that interdependence, indivisibility, and irreversibility together, under the condition of imperfect foresight, necessitate the existence of complex networks.

Part 1:

If there exists weak connectedness in the network, then $\exists x_h \notin C_i$ so that $(x_i, x_h) \in R$, for $x_i \in C_i$ and $x_h \in C_h$. Since the total number of links is fixed at nk, that is, $|R| = nk$, there must exist $C_h \neq C_i$ so that $\exists\, (x_h, x_g) \notin R$, where $x_h, x_g \in C_h$ and $x_h \neq x_g$, or $\exists\, (x_i, x_j) \notin R$, where $x_i, x_j \in C_i$ and $x_i \neq x_j$, which leads the network to an unordered one. In words, if there exists weak connectedness, then at least one clustered set is not ordered because the total number of links is fixed at the maximum of nk, resulting in an unordered network.

Part 2:

According to Definition 5, because of indivisibility and irreversibility, for each clustered set C_i, $\forall\, x_j, x_k \in C_i$, $j \neq k$, so that x_j and x_k are strongly connected, excluding the possibility that the network is random.

Part 3:

From Part 1 and Part 2, since weak connectedness implies the impossibility of an ordered network and indivisibility and irreversibility imply the impossibility of a random network, we can conclude that given weak connectedness, if there exist indivisibility and irreversibility, the network is neither ordered nor random, and must be complex.∎.

Lemma 2. *That plans work implies that decisions are interdependent, indivisible, irreversible, and imperfectly foresighted.*

Proof:

The strategy of the proof also includes three parts. Firstly, we prove that plans work in terms of increasing the total expected utility of the network for the planner implies weak connectedness. Secondly, we prove that plans work implies indivisibility and irreversibility. From Part 1 and Part 2, we can conclude that plans work implies the four I's.

Part 1:

In the general case, assume that there exists at least a clustered set in the network under consideration and that x_i and x_j, where $i \neq j$, belong to the set and are strongly connected by assigning a problem with negative utility to one of the two decisions, say x_i. There must exist a decision x_h outside the clustered set in the network with the minimum probability $P(x_h) < P(x_i)$ and $P(x_h) < P(x_j)$ so that if x_i is reconnected to x_h through a plan by reassigning that problem to x_h (Definition 11), then the total expected utility of the network for the planner will be increased by the amount of the negative of $u(P(x_i) - P(x_h))$, where u is the negative utility associated with that problem. For this logic to obtain, the network must be weakly connected (Definition 4). Note that the same logic of proof applies to assigning solutions with positive utility.

In the special case where there is more than one decision with the minimum probability of occurring, assume that these decisions are evenly scattered in the network and that the network is ordered. Reconnecting the decision in the clustered set with the minimum probability of occurring from x_i to the one that is outside the clustered set is still desirable because this would reduce the connection cost of the network due to shortened path length (Watts & Strogatz, 1998).

Part 2:

In the general case, suppose x_i is the decision with the minimum probability of occurring in a clustered set C_i so that $P(x_i) < P(x_j)$ and $P(x_i) < P(x_h)$, where $x_i, x_j \in C_i$ and $x_h \notin C_i$. Reconnecting x_j from x_h to x_i by assigning the problem from x_j to x_i instead of x_h will increase the total expected utility of the network for the planner from $uP(x_h)$ to $uP(x_i)$. The resulting network must be an ordered one which in turn implies indivisibility and irreversibility (Definition 5).

In the special case where there is more than one decision with the minimum probability of occurring and the network is random, reconnecting x_j from a decision outside the clustered set to x_i by reassigning the associated problem will not change the total expected utility of the network for the planner, but is still desirable because such reconnection would result in the transformation of the random network to a small world network with a smaller cost of connection (Watts & Strogatz, 1998).

From Part 1 and Part 2, we can conclude that for plans to work requires reconnecting decisions through problems or solutions assignment to increase the total expected utility of the network for the planner, and that the resulting topological structure of the network must imply the four I's.∎

***Theorem**: Plans work in complex network systems*

From Lemma 1 and Lemma 2, we can conclude that plans work implies complex systems.

Proof:

The theorem obtains through the logical inference from Lemma 1 and Lemma 2, since the four I's imply complexity and effectiveness of plans implies the four I's.∎

5. Discussion

In the present paper, the city is conceived as a giant, dynamic network of decisions. The model based on which the axiomatic proofs are carried out is called the Spatial Garbage Can Model (Lai, 2006) which has been partially validated (Lai, Kuo, and Yu, forthcoming) in that the computer simulation results are consistent with the empirical findings. Though the SGCM is a direct transposition from the garbage can model (Cohen et al., 1972), viewing cities and organizations as both complex systems which presumably have common properties, we would argue that the conceptual formulation of the garbage can model could be transposed directly to its special version. The model is so rich that it has been used to prove through computer simulations that cities are dissipative structures (Lai, Han, & Ko, 2013), to explain the origins of urban institutions (Lai & Han, 2015), and to develop a planning technology (Lai & Huang, 2017). It could be reformulated to address the issue of coalitions in relation to plans (Hopkins, 2014).

The results of the axiomatic analysis might prompt us to return to and focus on plans for urban development, rather than policies (Hopkins, 2014). That said, it must be reminded that human settlement improvement through managing urban complexity relies on other modes of decision coordination, namely, administration, regulations, and governance (Hopkins, 2001). Coordinating decisions connotes arranging decisions in space and time so that the outcome of such arrangement yields an acceptable level of satisfaction. The decisions are interdependent and can be made by the same decision maker or by other decision makers. There can be four modes of coordinating decisions: planning, administering, regulating, and governing. A plan is a path in a decision tree that takes into account possible alternatives and uncertain outcomes and can be analyzed through the decision analysis framework. Effective administration depends on useful organizational designs in that organizations are manifestations of decision coordination. Plans and organizations thus complement each other. Regulations identify permissible rights for the decision maker to act. Governance implies collective choices. Managing urban complexity requires all four modes of decision coordination, that is, planning, administering, regulating, and governing, or PARGing, cities. In particular, plans coordinate decisions through information; administration coordinates decisions through authorities in organizational design; regulations coordinate decisions through rights; and governance coordinates decisions through collective choices, all bringing about order in the background of urban complexity. In terms of purposes, plans tend to cope with the problems of dynamics failure; administration deals with the problems of government failure; regulations cope with the problems of market failure in relation to externalities; and governance deals with the problems of market failure in relation to collective goods (Lai, 2017).

We have not dealt with time explicitly. The parameter of time could be incorporated into the definitions of the structure of a network as depicted in Section 3. For example, each decision and relation could be added by a subscript to indicate time. We suspect that this would confound the model while resulting in the same conclusions as those derived without the time parameter.

Definition 11 depicts what a plan is for the planner in a snapshot. However, in reality the planner might own multiple plans, rather than single one. Each plan is a sequence of contingent, related decisions and these plans interact with each other. In addition, there may be multiple planners with multiple plans that interact with each other. The current formulation of the axiomatic system could be extended to consider the more complicated situations of multiple planners with multiple plans.

The traditional way of dealing with time is in the planning process to specify a planning horizon with a set of planning intervals. Planning horizon is the period of time through which the plan foresees the future, while a planning interval is the period of time the plan is referred to in making decisions. For example, in a plan for managing urban growth boundaries, the planning horizon covers usually 20 years, while the planning interval spans usually five years. That is, the 20-year plan will be revised every five years. There can be two approaches to plan revision: time-driven an event-driven (Knaap & Hopkins, 2001). In the time-driven approach, the plan will be revised at the end of a fixed time interval, while in the event-driven approach, if the system reaches a threshold, such as the amount of land available for development is below a standard, the plan revision will be activated; otherwise, there is no need for plan revision. We argue that the event-driven approach is more effective than the time-driven approach in terms of cost saving (Han & Lai, 2012). Therefore, it can be argued that the planner might have multiple plans with different planning horizons. What makes the planning activity more complicated is that each plan is revised according to the event-driven approach to planning intervals, so that these intervals are not fixed for each plan and confound the planning process.

6. Conclusions

That plans work in urban development is a claim that lacks theoretical and empirical backing. In the present paper, based on a realistic model of cities as giant, dynamic networks of decisions in which plans and the planner are embedded, we provide a partial answer to this fundamental question by proving axiomatically that plans work in complex network systems of which cities are a manifestation. The theorem reached from the axiomatic system provides a theoretical basis on which planning is practiced in the face of complexity. In particular, it implies that plan-based actions derived internally that consider multiple, linked decisions are more effective than decision-based actions that treat these decisions as independent, in particular in the face of complexity. The results might prompt us to return to and focus on plans as the object of planning research (Hopkins, 2014), but the caveat is that plans can only accomplish certain things and to improve human settlements through managing urban complexity, we need other modes of decision coordination, including administration, regulations, and governance.

Acknowledgement

The author is grateful to Shiu-Chien Kuo for his help in proving the theorem.

References

Alfasi, N., & Portugali, J. (2007). Planning rules for a self-planned city. *Planning Theory, 6*(2), 164–182.
Arthur, W. B. (1994). *Increasing returns and path dependence in the economy.* Ann Arbor, Michigan: University of Michigan Press.
Batty, M. (2005). *Cities and complexity: Understanding cities with cellular automata, agent-based models, and fractals.* Cambridge, MA: The MIT Press.
Batty, M. (2014). *The new science of cities.* Cambridge, MA: The MIT Press.
Byrne, D. (2003). Complexity theory and planning theory: A necessary encounter. *Planning Theory, 2*(3), 171–178.
Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A garage can model of organizational choice. *Administrative Science Quarterly, 17*, 1–25.
Hall, P. G. (1980). *Great planning disasters.* London: Weidenfeld.
Han, H., & Lai, S.-K. (2011). Decision network: A planning tool for making multiple, linked decisions. *Environment and Planning B: Planning and Decision, 38*, 115–128.
Han, H., & Lai, S.-K. (2012). Reformulation and assessment of the inventory approach to urban growth boundaries. *Land Use Policy, 29*, 351–356.
Hopkins, L. D. (2001). *Urban development: The logic of making plans.* London: Island Press.
Hopkins, L. D. (2014). It is about time: Dynamics failure, using plans and using coalitions. *Town Planning Review, 85*(3), 313–318.
Knaap, G. J., & Hopkins, L. D. (2001). The inventory approach to urban growth boundaries. *Journal of American Planning Association, 67*(3), 314–326.
Lai, S.-K. (2006). A spatial garbage can model. *Environment and Planning B: Planning and Design, 33*(1), 141–156.
Lai, S.-K. (2017). *Managing urban complexity through decision coordination.* Shanghai: Paper presented at the Annual Meeting of China Urban Management Discipline Development.
Lai, S.-K., & Han, H. (2015). Origins of institutions in cities: A modeling framework. *International Journal of Society Systems Science, 1*(2), 139–156.
Lai, S.-K., Han, H., & Ko, P.-C. (2013). Are cities dissipative structures. *International Journal of Urban Sciences, 17*(1), 46–55.
Lai, S.-K., & Huang, J.-Y. (2017). Theoretical foundation of a decision network for urban development. *Frontiers of Information Technology & Electric Engineering, 18*(8), 1033–1039.
Lai, S-K., S-C. Kuo, and K-W. Yu. "Empirical validation of the spatial garbage can model: A case of Taipei." City and Planniing, forthcoming (in Chinese).
Moroni, S. (2015). Complexity and the inherent limits of explanation and prediction: Urban codes for self-organizing cities. *Planning Theory, 14*(3), 248–267.
Nicolis, G., & Prigogine, I. (1989). *Exploring complexity: An introduction.* New York: W. H. Freeman and Company.
Portugali, J. (2008). Learning from paradoxes about prediction and planning in self-organizing cities. *Planning Theory, 7*(3), 248–262.
Prigogine, I., & Stengers, I. (1984). *Order out of chaos.* New York: Bantam.
Rauws, W., & De Roo, G. (2016). Adaptive planning: Generating conditions for urban adaptability. Lessons from Dutch organic development strategies. *Environment and Planning B: Planning and Design, 43*(6), 1052–1074.
Rittel, H. W. J., & Webber, M. W. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4*, 155–169.
Watts, D. J., & Strogatz, S. H. (1998). Collective dynamic of 'small-world' networks. *Nature, 393*, 440–442.
Yamu, C., De Roo, G., & Frankhauser, P. (2016). Assuming it is all about conditions. Framing a simulation model for complex, adaptive urban space. *Environment and Planning B: Planning and Design, 43*(6), 1019–1039.