Chapter 14
Learning from Paradoxes about Prediction and Planning in Self-Organizing Cities

14.1 Introduction

Since early days paradoxes have been useful (and enjoyable) analytical tools; mainly due to their capability to expose things that are wrong when everything appears to be right. Zeno paradoxes are a good example to their use in antiquity, while in modern science theoretical physics stands as a domain where paradoxes are intensively used. This is not the case with cities and their planning, however. This chapter introduces paradoxes as useful means to study predictions in the context of cities and their planning. It discusses several city planning paradoxes and suggests seeing their origin in the complexity of cities and in the role played by cognitive maps and information exchange in complex, self-organizing cities.

14.1.1 Achilles and the Tortoise

> *The Greek hero Achilles, the fasted man, conducted a footrace with the slow tortoise. Graciously, fast Achilles allowed the slow tortoise a head start of a hundred meters. But then, as the race started, something strange happened: during the time Achilles run the hundred meters that brought him to the tortoise's starting point, the tortoise "run" a certain much shorter distance, say one meter. During the time Achilles run that one meter distance, the tortoise advanced farther; and so it continued: whenever Achilles reached the tortoise's previous point, he still had farther to go and so on until infinity. Swift Achilles gradually realized that he can never overtake the slow tortoise.*

This is, of course, one of the famous paradoxes of 5th century B.C. pre-Socratic Greek philosopher Zeno from Elea in southern Italy. Aristotle is his Physics (VI:9, 239b 15) summarized it as follows:

> *In a race, the quickest runner can never overtake the slowest, since the pursuer must first reach the point whence the pursued started, so that the slower must always hold a lead.*

J. Portugali, *Complexity, Cognition and the City*, Understanding Complex Systems, DOI 10.1007/978-3-642-19451-1_14,

14.1.2 Paradoxes

As can be seen from the story about Achilles and the tortoise, a paradox "is an argument that starts with apparently acceptable assumptions and leads by apparently valid deductions to an apparent contradiction" (Aharonov and Rohrlich 2005, p 2). It is generally believed that Zeno was not the first to use paradoxes as means to convey ideas; that other philosophers of his time did so before him; however, his set of paradoxes is the first known documented example. The essense of this method is close to the method of proof called *reductio ad absurdum*, also known as 'proof by contradiction'. Both are often credited as a source of the dialectic method (Kains 1988).

A proof by means of a paradox "is useful because it can show that something is wrong even when everything appears to be right" (Aharonov and Rohrlich, ibid). For example, in Zeno's paradox the apparently acceptable assumptions, followed by the apparently valid deductions, entail a *reduction ad absurdum* that contradicts common sense. Such a discrepancy is of course challenging and indeed, Zeno's paradox provided an impetus for philosophers and mathematicians to solve it – in early times as well as today (Salmon 2001; Sainsbury 1995; Faris 1996).

Zeno's paradox is presented in contemporary mathematics courses to elucidate the concept of *convergence* of series: implicit in Zeno's case is the (false) assumption that each consecutive step is smaller than the foregoing one so that the sum of all these increments are finite and similarly also the time permitted. Within these *finite* limits Achilles indeed cannot overtake the tortoise. But when longer distances (times) are permitted, he can.

It might be added that even if the above-noted assumption were not false, still Achilles must win the competition: his body is built in such a way that he cannot make steps below a certain size so that the above assumption can be valid up to a threshold beyond which Achilles must overtake the tortoise. This argument about Zeno's paradox illustrates the importance of embodiment and scale. However, having said the above, it is important to emphasize that from the mathematical solution to the paradox follows that even if Achilles' body were a line, he would still win the competition – the solution has to do with convergence. (I'm indebted to Professor Haken for his comments about the above Zeno's paradox).

Throughout history, paradoxes have proved to be very useful and often enjoyable learning tools. In ancient times they were employed mainly in the domains of logic and philosophy. In the 20th century we see an intensive use also in other domains such as mathematics, economics, and physics. Wikipedia, for instance, lists 18 economic paradoxes. In theoretical physics, some of the central controversies of the 20th century have developed by means of paradoxes – especially those that concerned and still concern the relations between Einstein's relativity and quantum theory. Some of them, such as the EPR – Einstein, Podolsky, and Rosen (1935) thought experiment, and Schrödinger's cat (described below), became very famous indeed (and useful). It is thus not surprising that Aharonov and Rohrlich (2005) have entitled their book about the history and recent advances in theoretical physics *Quantum Paradoxes*.

Cities (like life) are full of paradoxes and so is also the realm of urban and regional planning. However, apart from a few exceptions, paradoxes have never played a significant role in the discourse about urban and planning theory. The first aim in this chapter is to demonstrate that theorizing by means of paradoxes has the potential to be a very useful learning tool in the discourse about, and study of, cities and their planning. In what follows I illustrate the usefulness of paradoxes by examining several real and imaginary urban and planning paradoxes and by discussing their theoretical foundations.

The various planning paradoxes that are discussed below arise from a discrepancy that to my mind characterizes the domain of urban and regional planning: On the one hand, planning theory, as well as the structure of planning law, practice and administration, are all based on the (usually implicit) assumption that cities are essentially predictable entities; that given sufficient data and information, their future behavior is in essence predictable. On the other hand, current urban theory suggests that cities are complex, self-organizing and nonlinear systems and that as a consequence their future behavior is in essence not predictable; even if sufficient information and data is collected and available (Portugali 2000 and above). The second and major aim of this chapter is to employ several imaginary and real prediction paradoxes as means to expose the above discrepancy and elaborate on it.

The discussion below is divided into two major parts: the first (Sect. 14.2) describes and examines four paradoxes. Its aim is to illustrate the usefulness of paradoxes in scientific discourse and to provide the data and background to the discussion that follows. The second part (Sect. 14.3), "learning from paradoxes", examines several phenomena and aspects that explain why the planning paradoxes arise. The chapter then concludes with a discussion about the implications to planning theory and practice and suggests further research directions (Sect. 14.4).

14.2 From Schrödinger's Cat to Planning Paradoxes

This section describes and studies four paradoxes in a sequence. The first is the famous Schrödinger's cat thought experiment (Sect. 14.2.1). It is "famous" for the impact it had on theoretical physics and on the philosophy of science, and for being a "classical" example of the role and usefulness of paradoxes in scientific discourse. As we shall see below, Schrödinger's cat provides also a theoretical context and source of inspiration to two planning issues that will be elaborated below in Sect. 14.3: SFFP – the phenomenon of self-fulfillment and self-falsifying predictions (Sect. 14.3.1) and the distinction between classical and self-organized urban and planning theories (Sect. 14.3.2). The *rbc paradox* that is described next (Sect. 14.2.2), takes us to the realm of cities, whereas the next two paradoxes, the imaginary prediction-planning paradox (Sect. 14.2.3) and the real prediction-planning paradox (Secs. 14.2.4) provide the main case studies to the discussion in Sect. 14.3 that follows.

14.2.1 Schrödinger's Cat

Here is the thought experiment as formulated by Schrödinger (1935, p 807) and as illustrated in Fig. 14.1:

> *A cat is penned up in a steel chamber, along with the following device (which must be secured against direct interference by the cat): in Geiger counter there is a tiny bit of radioactive substance, so small, that perhaps in the course of the hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The psi-function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts.*

In terms of interaction we can say that there are two interacting persons here: Person 1 who sets the box and Person 2 who opens it and finds the cat dead. The question is: who is the murderer? Classical physics answers that person 1 is the murderer! Quantum theory answers that person 2 is the murderer! The reason: until Person 2 opens the box (i.e. "observes"), the cat is at once dead and alive! (A third answer might be that both persons, 1 and 2, are the murderers: they murdered the cat by means of their interaction.)

Schrödinger's aim in setting this thought experiment was to expose the absurdity of the quantum answer: The idea that a cat can be at once alive and dead and that humans, by means of their act of observation, might affect the state of physical entities, contradicts human experience in the world of matter; hence the paradox. In retrospect we know that Schrödinger's cat paradox led not to the falsification of quantum theory but

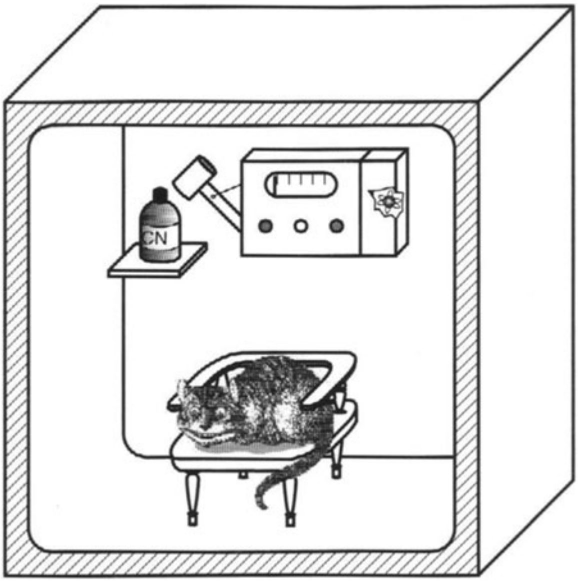

Fig. 14.1 Schrodinger's cat inside the steel chamber unaware of the Geiger counter, the radioactive atoms, the bottle of cyanide, and the hammer
Source: Aharonov and Rohrlich 2005, Fig. 9.1

rather to its elaboration by theories such as Everett's (1955, 1957) *the many worlds interpretation* (DeWitt and Graham 1973) and Bohm's notions of *causal interpretation*, *implicate order* and *ontological interpretation* (Bohm 1957, 1980; Bohm and Hiley 1993). These theories share the view that in the subatomic quantum domain, there are no external observers but rather interacting entities. In such a realm the observer by his/her act of observation participates and influences the process.[1] As we shall see in some detail below, while in the domain of matter this point of view seems astonishing, in the domain of cities and planning it is not; in fact it is specifically relevant to our understanding of the role of predictions and observation in the domains of complex systems in general and of cities and planning in particular.

14.2.2 The rbc City Paradox

Cities as noted are full of paradoxes. A well-known urban paradox that was associated with Alonso's (1964) 'trade off theory' and his notion of *rbc* (rent bid curves) went like this: The theory commences with three apparently acceptable assumptions that

- Urban phenomena (e.g., land value) decay with distance from the city center. This assumption is known as the "distance decay function".
- Land-use is determined by means of agents' competition over land.
- Demand for urban land decays with distance from the city center.

These apparently acceptable assumptions led to the following apparently valid deduction:

- The higher bidders capture the city center, the medium bidders the area beyond the center and the lower bidders the periphery.

The above deduction, in its turn, leads to an apparently acceptable conclusion:

- The richest agents capture the city center

Empirical evidence indeed supports this conclusion, but at the same time exposes an apparent empirical contradiction:

- The poorest agents too live at the center on the most expensive urban land.

As in many other paradoxes, this paradox has proved useful in that it provided an impetus to refine the theory (Harvey 1971, 1973; Portugali 1981) as described in Fig. 14.2.

But the above example is an exception; for while cities are full of paradoxes, paradoxes have never played a significant role in urban theory. In what follows I

[1]For a somewhat different view see Aharonov's notion of *weak measurements* (Aharonov and Rohrlich 2005). Most theoreticians of quantum theory would not subscribe to Everett's nor to Bohm's explanations. The reason being "decoherence" (Zurek 2003), namely, that the cat's fate is not that of a microscopic quantum system but rather of a macroscopic "classical" body. I'm indebted to Professor Hermann Haken for turning my attention to this point.

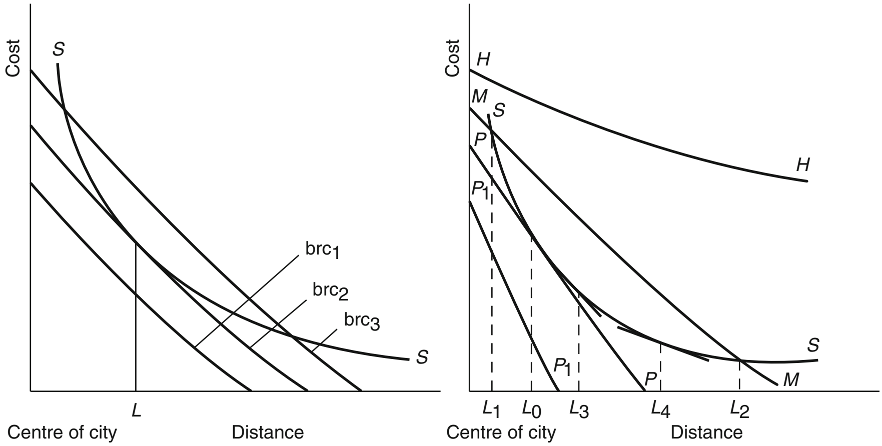

Fig. 14.2 In Alonso's mapping of the rent bid curves (*left*), equilibrium is reached on location *L* where the city land price curve (*S-S*) is tangential to the lowest of the bid rent curves ... (*brc2*). The *rbc* paradox entailed the recognition that the *rent bid curves* vary according to the economic state of the urban agents with the implication that the process of location is sequential (*right*): First come the rich with their flat *rbc* (*H-H*) that give them freedom of choice to live everywhere in the city. On the other hand, the poor with their very steep *rbc* (*P-P*) are forced to locate at L_0 only; finally the middle classes in between (*M-M*) have a choice to live in all locations between L_1 and L_2 (*Source*: Portugali 1981, pp 290–292, Figs. 5.6, 5.7)

look at some imaginary and real urban paradoxes and discuss their theoretical foundations.

It is important to clarify the term 'agent' as used above and as further employed in the discussion below. In both connections it is employed as it is common to use it in simulation models of complex systems (as in Part IV below). In the latter, every entity that is part of the system and its network, and participates in its interaction, is termed 'agent'. Thus in a city, every inhabitant or a person that is active in the city is an agent and so is each of the many private companies and public institutions that operate in the city.

14.2.3 An Imaginary Prediction Paradox

Imagine that you are an appreciated transportation expert in charge of monitoring a certain road network. The time is 7:30 a.m. and observing the incoming data by means of your transportation prediction models you see a traffic jam at junction X at 9:00 a.m. This finding puts you in a dilemma: If at 8:00 a.m. you announce your prediction in the radio – that at 9:00 a.m. there is going to be a major traffic jam at a certain junction – all commuting drivers will hear it and since they trust your prediction, they will avoid the junction and there will be no traffic jam there – your prediction will be falsified. If this happens you might loose your credibility as a predictor. The dilemma here is not just your personal reputation and ego, but its consequences; if in the next morning you predict another major traffic jam, drivers will not believe you and the event will happen as predicted. The general intuitive assumption is that the better a prediction, the greater are the chances that it will be materialized as predicted. The paradox in the above example is that the better a prediction is, the greater the chance that it will *not* be materialized.

The above paradox is typical to cases of *self-defeating* or *self-falsifying* predictions. A mirror image of the latter is the so-called *self-fulfilling predictions*. An example here might be a rather arbitrary prediction that thousands of people are planning to come tomorrow night to the big demonstration at the city center. Since people trust this prediction, many of them decide to go to the city center to see and participate in, the event. The paradox here arises because the example falsifies our intuitive assumption that the chances of an arbitrary prediction to materialize are very low. What we face here, as noted, is a case of self-fulfilling prediction. In Sect. 14.3.5 below we further discuss these issues.

It must be emphasized that the description above refers to a rather simplistic situation in which all receivers of the predicted information behave in a uniform way. As implied by the notion of 'semantic information' discussed above (Chap. 9, see also Sect. 14.3.6 below), in reality receivers of information might behave in a variety of ways that depend on their character, culture, social norms, and also on heuristics and other factors that participate in determining human behavior in situations of uncertainty. In order to capture this variety one thus has to investigate various behavioral patters and their implications. In fact, in Chap. 18 below I present some preliminary steps toward building an urban simulation model the aim of which is to study such processes. We hope to be able to report on some findings from this model in the future.

14.2.4 A Real Case of Planning Paradox

City paradoxes are specifically significant in the domain of city planning. This is so because of the very structure of the planning process: It typically starts with a set of assumptions and goals based on past experience, continues with a set of deductions-predictions about the future, followed by a set of actions that are assumed to meet the predictions (Chap. 12 above; see also Portugali 2000, Chap. 11). For example, past experience shows that the rate of growth (of, say, population) in the city is x. By means of deduction one can determine the future state of x. By means of a set of appropriate actions and policies the future demand can be supplied in the appropriate target year.

The planning paradox arises when a set of apparently acceptable assumptions about the past, followed by apparently acceptable deductions-predictions about the future, further followed by apparently acceptable policies and actions, lead to apparently contradictory results. Similarly to paradoxes in general, a planning paradox is useful because it can show that something is wrong even when everything appears to be right.

A real case of planning paradox due to self-falsifying prediction followed the immigration wave from the former Soviet Union to Israel in the early 1990s. The professional planning prediction was that Israel is approaching a housing shortage. The entailed plan was that the government should therefore purchase a large number of mobile houses and locate them on the outskirts of towns and cities. The implementation of this policy ended in failure due to spontaneous initiatives by a large number of individuals ("latent planners"), who, as a consequence of the predicted shortage and the prospect of making money, transformed existing non-residential buildings into residential ones. This they did mainly in city centers, which, from the point of view of newcomers, are the most attractive places. The outcome was that the vast majority of apartments prepared by the latent planners were rented, while many of the mobile houses prepared by the government's planning bodies were left unwanted and unoccupied (Alfasi and Portugali 2004).

On the face of it the above event can be interpreted as 'normal response of market forces' – which is true. However, as will be clarified below, the point is the implicit (wrong) assumption made by the planners that their predictions and plans are external to the events predicted. From the theory of complexity (below, Sect. 14.3.3) follows the exact opposite: that predictions and plans, once produced, become participants in a complex urban dynamics. This is the main reason why the 'normal responses of market forces' and of cities are hard to predict.

14.3 Learning from Paradoxes

The two prediction-planning paradoxes discussed above in Sects. 14.2.3, 14.2.4, are a consequence of SFFP. The discussion in this section starts by elaborating on the phenomena of SFFP. This discussion entails the question as to how these phenomena arise. The answer to this question starts with a distinction (inspired by Schrödinger) between *classical* and *self-organizing theory of planning* (Sect. 14.3.2) and continues by showing that the above prediction-planning paradoxes are a result of the fact that planners tend to treat complex self-organizing cities as if they are classical systems. This answer in its turn entails several questions that concern the nature of complex systems in general, the difficulties to predict their behavior, the uniqueness of cities as complex systems and the specific sources of their complexity. Sections 14.3.3–14.3.6 attempt to discuss these issues. Section 14.3 introduces in some detail the notion of self-organization and the problematic of prediction in such systems. Section 14.3.4 discusses the uniqueness of cities as *dual complex systems* and the implications thereof to prediction and planning, while the remaining two subsections suggest finding the sources of this uniqueness of cities and the implications to planning and prediction, in the roles played by memory (Sect. 14.5) and information (Sect. 14.6).

14.3.1 Self-Fulfilling and Self-Falsifying Predictions (SFFP)

The notion of self-fulfilling prediction or prophecy is a rather old one. It appears time and again in Greece mythology with the story of Oedipus being the most well-known one; it appears in Roman mythology in the story of Romulus and Remus, in the mythological story of Krishna (in the epic *Mahabharata*) and more.

In social and scientific discussions one can mention sociologist Robert K. Merton (1949) who in his *Social Theory and Social Structure* discusses the concept of the self-fulfilling prophecy in some length:

> *The self-fulfilling prophecy is, in the beginning, a* false *definition of the situation evoking a new behaviour which makes the original false conception come true... prophecies or predictions ... become an integral part of the situation and thus affect subsequent developments, This is peculiar to human affairs. It is not found in the world of nature, untouched by human hands.*

Philosopher Karl Popper (1976) goes one step further than Merton and suggests that this phenomenon that he called *the "Oedipus effect"* can be found in nature too:

> *One of the ideas I had discussed in The Poverty [of Historicism] was the influence of a prediction upon the event predicted. I had called this the "Oedipus effect", because the oracle played a most important role in the sequence of events which led to the fulfillment of its prophecy.... For a time I though that the existence of the Oedipus effect distinguished the social from the natural sciences. But in biology too – even in molecular biology – expectations often play a role in bringing about what has been expected.*

The notion of self-defeating prediction is less known and discussed. A case in point here is the so-called *Osborne effect*: In 1983, inventor Adam Osborne, founder of Osborne Computer Corporation (OCC), pre-announced several next-generation computer models which had not yet been built, highlighting the fact that they would outperform the existing model. According to the myth, sales of the Osborne 1 immediately plummeted as customers opted to wait for these improved systems; this caused an attendant drop in cash flow and thus profits, and a few months later the company became bankrupt.

14.3.2 Classical vs. Self-Organizing Planning Theories

The phenomena of SFFP arise when the predictor is not an external observer, but an internal agent in the multi-agent system under consideration; just like the other agents that are exposed to the prediction. The fate of the prediction in this case is determined by means of the interaction between the many agents of the system. In fact, Schrödinger's cat that was discussed above was exactly about this: in the subatomic quantum domain, he said, there are no external observers but rather interacting entities.

As already noted above, while in the domain of matter Schrödinger's setup is contradictory, in the socio-human domain it is rather common: predictions about the stock exchange participate in its behavior. The behavior of the market is determined by the interaction between the message predicted by agent 1 and its interpretation by agent 2: until agent 2 interprets agent 1's message (that is to say, "opens the box"), the prediction, like Schrödinger's cat, is at once dead and alive.

Theoretical physics had and still has a major influence on discourse about the nature of science and scientific method. Prominent figures in this domain, such as Thomas Kuhn, Karl Popper and others, have taken physics as their major case study. The discussion about the scientific method in its turn had a major influence on all sciences. The study of cities and planning was no exception: in its attempt to transform the study of cities into a science and planning into "rational comprehensive planning", it was strongly influenced by the discourse on scientific methods (Camhis 1979). It is therefore not surprising that the tension between the classical and quantum theories in physics has an echo in the domains of cities and planning.

This echo shows itself in the tension between what I suggest to call *classical urban and planning theory* and the recently emerging view that cities and planning are essentially complex self-organizing systems: On the one hand, one finds *classical urban and planning theories* that implicitly or explicitly treat cities as machines, urban scientists as external observers and planners as external experts. Location theory is a typical example of a classical urban theory, while rational comprehensive planning of a classical planning theory (Chaps. 2 and 12 above). On the other hand, there are urban theories that treat cities as systemic wholes, and scientists and planners as some of the many parts, agents and forces that participate in a complex and spontaneous urban game (Allen 1997; Batty 2006; Portugali 2000 and the present book of course). Complexity and self-organization theories of urban dynamics belong to the second group.

The prediction and planning paradoxes noted above are due to contradiction that arises from the fact that many urban scientists and planners tend to treat cities as classical systems overlooking the evidence that cities are complex self-organizing systems. For example, in the case noted above regarding the plans to meet the migration wave from the former USSR to Israel, the planners treated the planning field as if it was a classical system, not being aware to the intricacies of the complex ways their plans participate in the urban dynamics. What is it in complex self-organizing systems that makes them in essence unpredictable? To answer this question we have to look into the properties of such systems.

14.3.3 Prediction in Complex Self-Organizing Systems

Self-organization, as we've seen above, is a property of open and complex systems: open in the sense that they exchange matter, information and energy with their environments and complex in two senses: first, their parts are so numerous that there is no technical way to determine causal relations between them. Second, their parts form a complex network of interaction, with feed-forward and feedback loops, that makes the determination of causal relations in essence impossible. Such systems are typically characterized by nonlinearity, phase transition and fractal structure and the property of emergence.

Prediction in the context of complex systems such as cities is associated with four fundamental properties of such systems. First, the nonlinearities that typify cities imply that one cannot establish predictive cause-effect relationships between some of the variables. Second, many of the triggers for change in complex systems have the nature of mutations (Allen 1997). As such, they are unpredictable, not because of lack of data, but because of their very nature. Third, unlike closed systems, in complex systems, the observer, with his/her actions and predictions, is part of the system – a point made by Jantsch (1981) more than two decades ago and largely ignored since then (Fig. 14.3). In such a situation, predictions are essentially feed-forward loops in the system, important factors that affect the system and its future evolution with some interesting implications that include self-fulfilling and

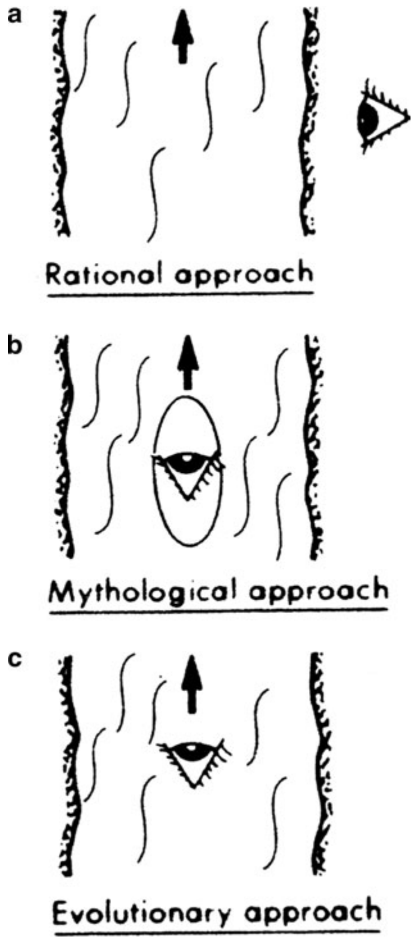

Fig. 14.3 Jantsch's (ibid Fig. 8) conceptualization of "the three modes, or levels, of perception and inquiry illustrated by the image of the stream. At the rational level we are outside the stream, at the mythological level we try to steer our canoe in the stream, but at the evolutionary level we are the stream" (ibid, caption)

self-falsifying or self-defeating predictions noted above. Fourth, cities as complex systems are different from complex systems commonly discussed by theories of complexity – they are, as noted several times above, dual complex or *dual self-organizing systems*.

14.3.4 Planning in Dual Self-Organizing Systems

As we've seen above, the main theories of complexity and self-organization were originally developed by physicists and by reference to physical phenomena such as liquid dynamics or LASER; at a later stage these theories were applied to cities – again by physicists. Thus, P. Allen (1997) has applied Prigogine's theory while Weidlich (1999) Haken's synergetics. As we've further seen, one of the major insights gained by our study *Self-Organization and the City* (Portugali 2000), was that there is a major difference between material and human systems: in material systems the parts are simple (atoms, molecules etc.) and complexity is an emergent property of the system as a whole. In human systems the situation is different: each of the parts (individuals, households, firms . . .) is in itself a complex system. Cities in this respect are *dual self-organizing systems*. The implications: First, the interacting elements in such systems are *agents* and not *parts*, that is, entities that have cognitive capabilities such as learning, thinking, decision making and the like; one of these capabilities is *planning* – agents plan and take decisions according to their past experience (learning) and their plans. That is, the interaction in dual self-organizing systems is between agents and their plans. Second, and as a consequence of the above, each agent, be it an individual person, a household, a private company or the city's planning authority, is a planner at a certain scale; and because of nonlinearities, the plan of a nonformal, small-scale planner might be more effective and influential than that of a formal, large-scale planner (see examples in Chap. 15 below and in Portugali 2006a, p 20).

14.3.5 Memory, Complexity, Prediction, and Planning

Memory is a very general notion referring to a variety of cognitive capabilities and tasks. Thus, in cognitive science it is common to distinguish between various forms of memory: long-term memory, working memory and so on (Roediger III, Marsh, and Lee 2001). Looking at the various forms of memory discussed in the literature, one can distinguish between forms of memory that refer to the past (retrospective memory, autobiographic memory, etc.) and forms of memory that refer to the future (e.g., prospective memory/remembering, aims, intentions). As elaborated in Chap. 13 above in some detail, planning is a basic cognitive capability in humans (Owen 1997) and a plan can thus be seen as a form of memory task that refers to the future.

Another form of memory that is significant to cities and planning is *cognitive map*. As discussed above (Chap. 6), a cognitive map is commonly defined as memory about large-scale extended space; there it has been suggested that "it would be useful to treat cognitive maps not in terms of a single meaning entity, but in terms of kinds of cognitive maps" (ibid). As an illustration we've discussed several forms of cognitive maps that included *autobiographic cognitive maps*, *prospective cognitive maps* and so on. To the above I suggest adding the view that a spatial plan – a city plan, for instance – is a cognitive map about the future.

In terms of complexity theory, plans can be interpreted as feedforward loops that affect agents' action in the city. For example, if you consider buying a house near a lot that is planned to be (say, 5 years from now) a site for a polluting installation, you are very likely to evaluate the house as if the polluting installation is already there; this, despite the fact that the lot is currently a beautiful open space and that not all city plans are eventually implemented. Your decision not to buy will function as a feedforward self-fulfilling loop.

Action in the city in its turn feeds back to agents' memory thus shaping their past forms of memory, including their retrospective cognitive maps. The latter then participate in shaping their prospective cognitive map and their entailed actions, and so on in circular causality. Such feedback processes are done either directly when the information about individual decision spatially diffuses in the city, or indirectly by individual actions that participate in shaping the global structure of the city that then feeds back to individual memories. As is well recorded, the existence of this complex network of feedback and feedforward loops is one of the properties that make systems complex in the first place. CogCity is an urban simulation model built in light of the above process (Chap. 18 below).

14.3.6 Prediction as Information

Predictions and plans are essentially kinds of information transmission. As we've seen above (Chap. 8), according to information theory (Shannon and Weaver 1949) the relevant entities in the process are the sender, the message, the channel and the receiver(s). As is well recorded, Shannon's main aim was to find a way to measure the quantity of information contained in a message going through a certain channel. And indeed, his main achievement was a definition of information as a pure quantity irrespective of the meaning enfolded in the message.

In Chaps. 8 and 9 above, we've elaborated on the distinction between *Shannonian information* which is "information" with meaning exorcised" and *semantic information*, which is information as used in everyday language, that is, information with meaning. Shannonian and semantic forms of information are further distinguished; first, by the property that Shannonian information is independent of the receiver, while semantic information is dependent upon the receiver – by the meaning attached to it by the receiver. Second, by the fact that Shannonian information is a property of simple and closed systems, while semantic information of open and complex systems.

Cities are *par-excellence* open, complex and as such self-organizing systems as we've seen above. We've further seen that in the context of cities (and complex open systems in general) Shannonian and semantic information are interrelated. Applied to predictions one can speak of *Shannonian prediction* and *semantic prediction*. In the first, the outcome of the prediction is independent of the receiver(s) while in the second it depends on the meaning attached to it by a receiver or receivers. A weather forecast is a good example for both: it has no effect on the climatic system, but it might affect the urban system – following the prediction people might behave in different ways that might entail phenomena of self-falsifying and self-fulfilling predictions as described above.

14.4 Concluding Notes

This chapter introduces paradoxes as useful means to study cities and their planning. It discusses several city planning paradoxes that are associated with the phenomena of SFFP and suggests seeing their origin in the complexity of cities and in the role played by cognitive maps and information exchange in complex, self-organizing cities.

The major lesson that must be learned from the discussion about the paradoxes is that planners have to take into consideration the implications of the complexity of cities and regions. Namely, that due to phenomena of SFFP that typify complex systems, prediction is problematic and the expectations that plans will be implemented as planned is not realistic. This situation entails several questions. First, can there be an alternative to prediction as a basis for planning? Second, is every planning act in the city subject to self-organization? Third, what then is the role of planning in the context of a complex system such as a city?

The answer to the first question is positive: As we'll see below (Chap. 16) planning need not rely on predictions but rather on planning rules that concern the relations between the various elements that compose a city. The answer to the second question is negative: Some planning acts are and must be fully predictable and controlled while others need not. This view follows the distinction suggested in Sect. 13.3.2 above between *classical* vs. *self-organized planning*. Classical planning refers to a relatively simple "closed system" planning process; closed in the sense that it is, or rather should be, fully controlled. *Self-organized planning* refers to a relatively complex "open system" planning process, which like other open and complex systems exhibits phenomena of nonlinearity, chaos, bifurcation and self-organization (Portugali 2005, p 21). In fact, both forms of planning exhibit themselves in many planning acts. For example, the planning of a bridge must proceed as a classical, closed-system planning act in the sense that there is no point starting such a project unless we have full control on the outcome. Self-organized planning starts to play after the bridge is completed – once it is built it triggers a complex urban dynamics that makes its impact on the city as a whole unpredictable and uncontrollable. This is true with respect to the planning of a relatively simple object such as a bridge, and even more so with respect to master plans, development plans and other forms of large-scale city planning.

The answer to the third question follows from what has been said above: in the context of complexity, plans do not determine or control the development of the system concerned (a city, a region etc.), but rather become participants in a multi-agents planning game. This is so with respect to plans made by formal planning agencies (e.g., the city's planning authority, a professional private planning office, etc.) and this is so with respect to a nonformal planning act made by an individual household, for instance; due to nonlinearity the nonformal plan might have a much stronger impact than the formal one (for an example see Chap. 15).

Paradoxes are useful mainly because of their capacity to expose things that are wrong even when everything appears to be right. Paradoxes are also a lot of fun. By means of paradoxes we have exposed and discussed several specific issues that concern the more general question of the relations between planning and self-organization. A full-scale discussion of this general issue extends beyond the frame of the present chapter and requires a separate discussion that we hope to develop in the future.