Land Use Policy 29 (2012) 351–356

Contents lists available at ScienceDirect

Land Use Policy

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

Reformulation and assessment of the inventory approach to urban growth boundaries

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ARTICLE INFO

Article history:
Received 18 May 2011
Received in revised form 30 June 2011
Accepted 13 July 2011

Keywords:
Decision network
Plans
Decisions
Inventory control
Urban growth boundaries

ABSTRACT

Based on the theoretical framework, in this article we demonstrate how *Decision Network* can be used to formulate the inventory approach to urban growth boundaries (UGBs) as an application of the planning tool to a general case. In particular, in the inventory approach expansions of UGBs are considered as decision situations, land consumptions as problems, and order sizes of UGBs as solutions. We compare the time- and event-driven systems of the inventory control problem based on the decision network framework. The former in the framework is considered as making single, independent decisions in time, whereas the latter as making multiple, linked decisions in time. Our numerical example shows that the event-driven system is more effective than the time-driven system in that the former incurs less total cost than the former in the UGBs context. The implication is that making multiple, linked decisions, as manifested by *Decision Network*, would yield more benefits, such as lowering the total cost, to the planner than making these decisions independently.

Introduction

Urban planners are usually faced with making multiple, linked decisions, rather than single, independent ones. Traditional decision analytical tools for making single decisions are insufficient for planners to deal with complex urban problems. We have depicted the theoretical and conceptual framework of a planning tool, *Decision Network*, specific for planners to make multiple, linked decisions (Han and Lai, 2011). In the present paper, we will demonstrate how *Decision Network* can be used to analyze multiple, linked decisions in a planning context through a general story on expansion decisions of urban growth boundaries (UGBs). In the general story, drawing on two inventory approaches to urban growth boundaries, that is, time-driven and event-driven systems (Knaap and Hopkins, 2001), we will use *Decision Network* to demonstrate that while time-driven systems are commonly practiced, event-systems are more effective in terms of the overall cost of managing urban growth. More specifically, we argue that time-driven systems of urban growth boundaries are equivalent to making independent expansion decisions in time while event-driven systems making multiple, linked such decisions. We choose the story of urban growth boundaries as an application of *Decision Network* because UGBs involve multiple actors with complex processes, have significant effects on urban development, and are widely practiced. Though the literature on urban growth management through UGBs is large, many controversial issues still remain unresolved, including, among others, the timing and sizes of UGBs expansions. Since our purposes here are to demonstrate how *Decision Network* functions in such complex situations, we do not intend to deal in depth with policy implications of UGBs from the application. In "The conceptual framework" section, we introduce the conceptual framework of *Decision Network*. In "The inventory approach to UGBs: a general story" section, we reformulate and compare the time- and event-driven systems of the inventory approach to UGBs based on the decision network framework. In the "Discussion" section, we discuss some implications of the results from the comparison. In the "Conclusions" section we conclude.

The conceptual framework

Decision Network is composed of a network of decision nodes. Like a decision area in the strategic choice approach (Friend and Hickling, 2005), each node is a decision situation with a finite number of options in it (see Fig. 1). Like a choice opportunity in garbage can model (Cohen et al., 1972), each decision situation is associated with four inputs, that is, decision makers, problems, solutions,

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doi:10.1016/j.landusepol.2011.07.005

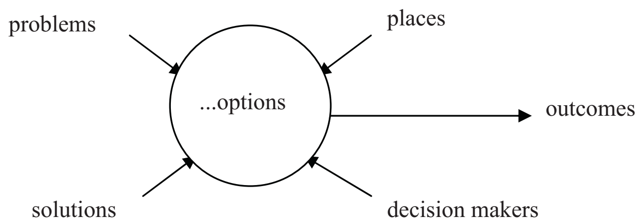

Fig. 1. A decision situation.

and places. Like an arc in decision tree (Kirkwood, 1997), an outcome emanating from the decision situation under consideration to another serves as one of the four inputs of the latter, thus forming a network (see Fig. 2). Each option within a decision situation is associated with a utility measurement. Each decision situation is also associated with a probability, meaning that it is stochastic and that the decision situation may or may not be realized or encountered by the planner. Given the conceptual framework, the problem is then to find a path as plan in the decision network that maximizes the subjective expected utility. The logic of this construct can be formalized mathematically and a hypothetical numerical example is given by Han and Lai (2011) to demonstrate how the logic works. The reader is encouraged to consult that work for how decision network functions in detail.

The inventory approach to UGBs: a general story

In arguing for the event-driven approach to UGBs in contrast to the time-driven approach, Knaap and Hopkins (2001) consider expansions of UGBs equivalent to an inventory control problem. In the time-driven approach, UGBs are usually adjusted and expanded at five-year intervals to supply sufficient land for consumption in a 20-year planning horizon, regardless of the growth rates of land for urban use. On the other hand, in the event-driven approach, the UGBs are expanded once the remaining stock of developable acres reaches a minimum threshold caused by land consumption to prevent the land market from price inflation and other negative effects on urban development, such as overbuilding and congestion. Time-driven systems are commonly practiced by local governments because they are easier to implement with less administrative cost, but susceptive of land price inflation due to monopoly pricing (Knaap and Hopkins, 2001). The event-driven systems are more flexible, on the one hand, in determining when to expand the UGBs to avoid the stock of developable acres dropping below a predetermined level, but they tend to be more costly because frequent monitoring is needed. With careful devices, such as lead-time inventory, safety-stock inventory, and market-factor inventory, Knaap and Hopkins (2001) formulate and argue for the

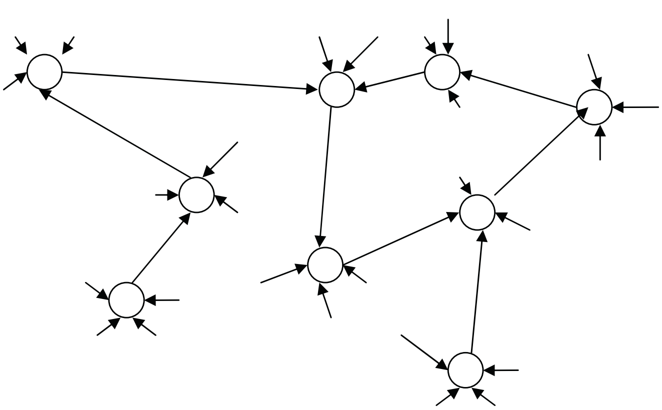

Fig. 2. A decision network.

inventory approach to UGBs of event-systems to be superior to that of time-systems as commonly practiced. The interested reader is encouraged to refer to their arguments there. In the present paper, we demonstrate that the inventory approach to UGBs of time- and event-driven systems can be reformulated as two decision networks: independent and linked respectively, and show through a numerical example, the inventory approach to UGBs based on event-driven systems is more effective than that based on time-driven systems.

Drawing on Knaap and Hopkins (2001) example, let t_0, t_1, t_2, t_3, and t_4 denote 2005, 2010, 2015, 2020, and 2025 respectively when UGB expansions are made in the time-driven system. Assume that the growth rates of urban development in five-year intervals are 2500, 1500, 2000, 1700, and 2000 acres per year, and denoted as r_0, r_1, r_2, r_3, and r_4 for the intervals from t_0 to t_1, t_1 to t_2, t_2 to t_3, t_3 to t_4, and t_4 to t_5 respectively. In order to compare the effectiveness of time- and event-driven systems, we focus here on the change in the stock of developable acres for the first 20 years, that is from 2005 to 2025. Effectiveness is determined by three factors: holding cost, order cost, and deficiency cost. Holding cost is incurred by keeping the stock of the total developable acres from being developed. For simplicity, it is assumed to be one dollar per acre and increases with the size of developable acres. Order cost is incurred by the UGB expansion decision when necessary. It is assumed to be one dollar per acre, setting aside the factor of economy of scale. Reduction of UGBs is further assumed to yield revenues at one dollar per acre. Deficiency cost occurs whenever the stock of developable acres is less than the predetermined threshold level and is assumed to be $10 per acre because of the risk of overbuilding and price inflation in land market. Assume further that the initial designation of the UGBs includes 40,000 developable acres because the expected growth rate is 2000 acres per year in the beginning of the inventory cycle with 20 years of land consumption and the developable acres will be depleted after then. In addition, the predetermined threshold level is assumed to be 30,000 acres below which price inflation would soar.

Given these initial parameters, the inventory approach to UGBs can readily be translated into a decision network problem. For the time-driven system, UGBs expansions are made at t_0, t_1, t_2, t_3, t_4, and t_5, whereas those for the event-system are uncertain depending on when the amount of developable acres in the UGBs falls below the threshold level, that is 30,000 acres. Each expansion can be considered as a decision situation with land consumption as problems, land supply or UGBs expansions (or order size in terms of the inventory control problem) as solutions, and mayors, public officials, landowners, developers, and planners as decision makers. Though expansions of UGBs are apparently a complex process involving multiple actors and because our focus here is on formulating and comparing the time- and event-driven systems of the inventory cycle using *Decision Network*, we set aside here the complex process as a topic in "Discussion" section by treating contributions of decision makers as negligible compared to the problems of land consumption and the solutions of UGBs expansion. That is, to simplify we ignore the elements of decision makers in the following decision network frameworks.

Decision network formulation of the time-driven system

Fig. 3 depicts the decision network formulation of the inventory approach to UGBs based on the time-driven system. There are four decision situations of UGBs expansion occurring at different times of t_0, t_1, t_2, and t_3 and denoted as d_0, d_1, d_2, and d_3 respectively, all of which being deterministic with a probability of one. Decision maker i is denoted as dm_i, solution j as s_j, and problem k as p_k. Note that in this decision network, problems, solutions, and decision makers are connected to one and only one decision situation,