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Simulating land use change in urban renewal areas: A case study in Hong Kong

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ABSTRACT

A considerable amount of research has been conducted on land use change, as it is extremely helpful when it comes to decision-making and policy formulation. Although land use change in urban renewal areas differs from that in new towns, very little research has focused on urban renewal and even less at the local or district level where most decisions need to be made. This study therefore developed a model for simulating land use change in urban renewal districts by combining the conversion of land use and its effects at small regional extent (CLUE-S) model and the Markov chain prediction model. The Yau Tsim Mong district of Kowloon in Hong Kong was the study area for the simulation, and historical land utilization data from 2000 to 2009 was used to validate the proposed model. By applying the validated model, four future land use scenarios were simulated for 2018 (the baseline scenario, the open space scenario, the residential scenario and the balanced scenario). The results not only indicate the effectiveness of the proposed model but also provide alternatives for future urban renewal based on different policy directions taken in the land use planning process.

Introduction

Land use change is a both locally and globally significant ecological issue (Agarwal, Green, Grove, Evans, & Schweik, 2002). Considerable effort has been made to explore its mechanisms and impacts. Vitousek (1994) indicated that land-use/land-cover change is one of three well-documented global changes, and Foley et al. (2005) published a review paper on the global consequence of land use. Some researchers have focused on land use change problems globally (e.g., Houghton, 1994; Turner, Meyer, & Skole, 1994) while others have focused on the issues at a continental or national level. For example, Zhao et al., (2006) identified the most pervasive land use changes in Asia and discussed their ecological consequences. Reginster and Rounsevell (2006) applied a multilevel analysis to constructing four scenarios of future urban land use in Europe. Spatial land use change in China from 1995 to 2000 was explored by using remote sensing data from that period (Liu, Liu, Zhuang, Zhang, & Deng, 2003). At the regional level, Pijanowski and Robinson (2011) analyzed spatial and temporal land use change in the Upper Great Lakes states of the USA. The spatial patterns of urban sprawl in the Flanders–Brussels region of Belgium were studied, as one of the most urbanized regions in Europe (Poelmans & Van Rompaey, 2009). At the city level, land use change involves urbanization and redevelopment processes. A better understanding of land use change mechanisms and dynamics can provide guidance for future urban development and redevelopment. For example, land use change in Beijing, China, was investigated and predicted by combining remote sensing, Geographic Information System (GIS), and other methods (Wu et al., 2006). Land use planning aims at influencing future land use change and achieving a balance between environment and stakeholder needs (Verburg et al., 2002). Simulating the degree and mechanism of land use change can facilitate the planning process (Agarwal et al., 2002; Batty, 2001). For example, regional land use change simulation was conducted to support local government to make decision on the prioritization of land development, land utilization, land harness and land protection under the background of development priority zoning (DPZ-led) strategy in China (Wu, Peng, Zhang, Skitmore, & Song, 2012).

Land use change detection in urbanization/urban growth/urban sprawl (e.g. Alphan, 2003; Henríquez, Azócar, & Romero, 2006; Xiao et al., 2006; Zanganeh Shahraki et al., 2011), as well as ecological and environmental impacts of land use change (e.g. Pauleit, Ennos, & Golding, 2005; Tang, Engel, Pijanowski, & Lim, 2005; Zhao et al., 2004) were the main themes of previous

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studies. Urban renewal, as one valuable opportunity to re-use land and further improve urban sustainability, has attracted much research interest (e.g. Wang et al., 2014; Zheng, Shen, & Wang, 2014). The land within the boundary of the redevelopment project is necessarily re-planed for future use when a redevelopment project is started (Bagaeen, 2006). However, since few researchers have paid attention to it, there is a potential for research on land use change mechanisms in the urban renewal process.

Hong Kong, like many developed cities, is facing urban problems such as urban decay, the shortage of land supply, and environmental deterioration. Urban renewal has been proposed as a policy approach to solve these problems. For example, Hong Kong's Urban renewal Authority has undertaken more than 50 redevelopment projects since 2001 (Development Bureau, 2011). However, decision-making must be improved at the local level for the sustainability (Allen, Lu, & Potts, 1999). This research was therefore conducted with the aim of simulating land use change in the Yau Tsim Mong (YTM) district of Kowloon, Hong Kong, which is a developed area and has experienced fast development and redevelopment in recent decades. The Markov chain prediction model was employed to predict temporal land use change. The Conversion of Land Use and its Effects at Small regional extent (CLUE-S) model was selected to conduct spatial simulation. This model is appropriate for small-scale land use change simulation and is able to simulate changes of different land use types simultaneously. Additionally, land use and planning policies, which cannot be easily considered in other models, have significant influence on the trend of land use change; the CLUE-S model allows for these spatial policies in its settings. This research used a series of historical land utilization data (the years of 2000, 2003, 2006, and 2009), which were prepared by using Geographic Information System technology, to develop, calibrate and validate the combined simulation model. To further facilitate decision-making on land use of urban renewal, future land use patterns in 2018 under four different scenarios were simulated by the validated model. The results of this study contribute to a comprehensive understanding of complex mechanisms of land use change and offer a valuable reference for land use planning and management in urban renewal districts.

Land use change model

Various models are widely applied for exploring land use dynamics and predicting future land use change in order to enhance decision-making. Models are helpful tools for understanding the complex mechanisms of social, economic and physical variables that influence land use change, and for evaluating land use change impacts (Braimoh & Onishi, 2007; Verburg, Schot, Dijst, & Veldkamp, 2004), both of which facilitate informed decisions (Costanza & Ruth, 1998) and improve land use planning and land-related policies (Braimoh & Onishi, 2007). Some models can also support decision makers in predicting future scenarios (Agarwal et al., 2002; Verburg et al., 2004).

Cellular automata (CA) are often applied to simulate spatio-temporal land use change (Al-Ahmadi, See, Heppenstall, & Hogg, 2009; Liu, 2012; Stevens & Dragicevic, 2007; Vaz, Nijkamp, Painho, & Caetano, 2012). The current state of cell depends on its previous state and its neighborhood based on a set of rules (Santé, García, Miranda, & Crecente, 2010). A cellular automata model has the advantages of spatial explicitness defined by rules and powerful computation ability obtained from artificial intelligence, thus can be developed through a combined method (Liu, Feng, & Pontius, 2014). It was firstly applied to geographic modeling in the 1970s (Tobler, 1979). In the 1980s, some researchers have begun to investigate urban expansion by applying CA-based models (Batty & Xie, 1994; Couclelis, 1985). Among various applications of CA, studies on the transition rules have obtained much attention since the transition rules are the core component for CA modeling. Many techniques are developed to capture the transition rules, ranging from logistic regression (Wu, 2002), colony algorithm (Liu, Li, Liu, He, & Ai, 2008), Simulated annealing (SA) algorithm (Feng & Liu, 2013) and support vector machines (Huang, Xie, Tay, & Wu, 2009). This approach is appropriate for short-term predictions although it cannot predict changes when the demands for different land-use types change. The CA approach can only simulate the conversion of one land use type in most cases (Verburg et al., 2002).

At the micro-level, multi-agent system models are the most popular. These models analyze the decision-making process of key stakeholders in a given system (Parker, Manson, Janssen, Hoffmann, & Deadman, 2003). Multi-agent models usually work as a function of individual decision-making agents, their interactions and related social process (Matthews, Gilbert, Roach, Polhill, & Gotts, 2007). This kind of model enables combination of subsets of various ancillary data and discrete variables (Jokar Arsanjani, Helbich, & de Noronha Vaz, 2013). The agents can model human behavior more precisely and facilitate better

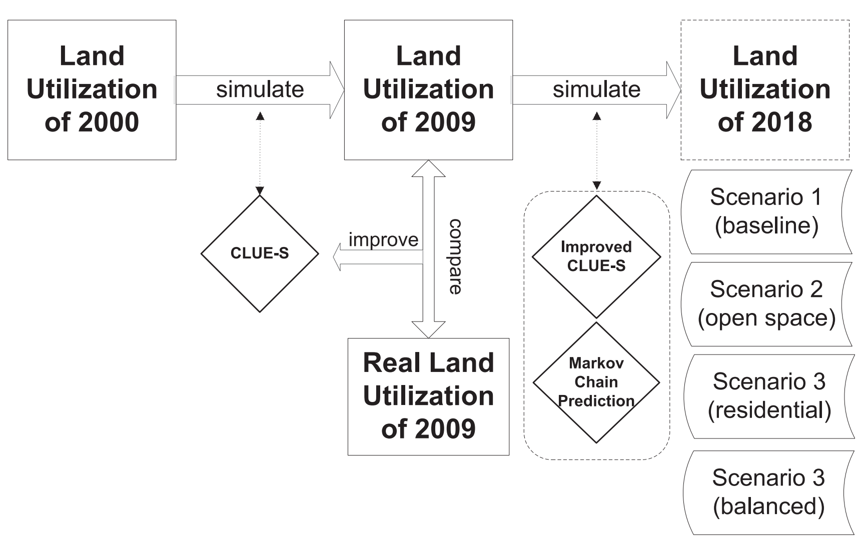

Fig. 1. Flowchart of the research methodology.