International Journal of Sustainable Built Environment (2015) 4, 359–377

Gulf Organisation for Research and Development

International Journal of Sustainable Built Environment

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Original Article/Research

# How will Dhaka grow spatially in future?-Modelling its urban growth with a near-future planning scenario perspective

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Received 5 March 2015; accepted 6 July 2015

**Abstract**

Being the primate city of Bangladesh, higher population growth and inward migration from rural areas is making Dhaka to experience an unprecedented level of urbanisation. This has brought two-fold implications-pushing it high up the mega-city size ladder while also posing the planners and city managers with more complex spatial and socio-economic challenges to deal with the rapidly expanding urban footprint. Updating the knowledge and evidence-base of Dhaka's urban growth dynamics becomes increasingly crucial for better functioning of its strategic urban planning and management. Therefore, this research seeks to broaden our knowledge of understanding spatial urban growth patterns and processes of Dhaka over the period of 1988–2005. Hybrid spatial modelling frameworks, incorporating statistical models (in the form of weight-of-evidence approach) along with cellular automata functions, therefore, have been used to comprehend the dynamism of rapid urban growth from 1988 to 2005. As expected, the local version of the transition probabilities (where Dhaka was divided into 18 Spatial Planning Zones), produced improved results compared to the global version (i.e. the whole of the Dhaka metropolitan area). The modelling framework has further been tested as a planner's 'what-if' simulation box to generate near-future scenario using future policy dataset. It appears to have sufficient experimental potential to implement more extensive spatio–temporal land-use modelling process even in sparse data environment such as Dhaka.


*Keywords:* Urban growth; Cellular automata; Urbanisation; Land use land cover change (LUCC); Dhaka

## 1. Introduction

Urban growth dynamics and their interaction with other land-uses are intrinsically complex, and hence is a potential field of contemporary research in Land use land cover change (LUCC). Yet, only recently, LUCC is being captured and modelled for cities in the Global South, where majority of the global urbanisation is taking place (UN, 2012). Using GIS and remote sensing based monitoring, accompanied by spatially explicit urban growth models (e.g. Angel et al., 2005; Barredo and Demicheli, 2004; He et al., 2006; Henriquez et al., 2006; Godoy and Soares-Filho, 2008; Cheng and Masser, 2003, 2004; Dewan and Yamaguchi, 2009), such, can strengthen the outdated evidence base of real world growth dynamics. Hence, based on past and present growth trends,

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Peer review under responsibility of The Gulf Organisation for Research and Development.

http://dx.doi.org/10.1016/j.ijsbe.2015.07.003

socio-economic and biophysical factors and land-use interactions, purpose-led use of such models can support present-day urban planning policies and their future formation (He et al., 2006; Hu and Lo, 2007; Irwin and Geoghegan, 2001; Verburg and Schot, 2004). Additionally, such models based on historical data can be extended to make simulation for the future under different scenarios or 'what-if' conditions. Such exploration of future land-use as scenarios are effective ways to anticipate future changes, to identify potential areas of rapid change which might require more rigorous analysis, or areas that need further attention for policy intervention in a timely manner (Kok et al., 2007; Verburg and Schot, 2004).

Dhaka, one of the oldest major cities in South Asia, has been the largest city in the present Bangladesh region for a period of about 400 years (Islam, 2005; Ahmed et al., 2014b). It has continued to urbanise rapidly after its independence in 1971. Since then urban growth became rapid, particularly in recent decades, and its city authorities are losing control of urban growth and development management (Mahtab-uz-Zaman and Lau, 2000; Islam, 2005; Ahmed et al., 2014b). Besides, higher population growth, rapid and consistently high inward migration from rural areas, and better job opportunities than other cities reinforced governmental policies towards Dhaka's expansion. The present Structure Plan[2] of the Capital City Development Authority's (RAJUK) recommends the outward expansion of the city by transforming suburban and agricultural land to cater this rapid demand for urbanisation. Recent and past research/studies on Dhaka's urban growth (Chowdhury and Faruqui, 1989; Dewan and Yamaguchi, 2009; Dewan et al., 2010; Islam, 1999, 2005; Nilufar, 1997; Rajuk, 1997; Roy, 2008) have already recognised Dhaka's problem in expanding horizontally due to flood risk or continuous encroachment on natural depressions/wetlands and khals[3]. Therefore, it is certain that future urbanisation in Dhaka presents enormous spatial and socio-economic challenges. Nevertheless, the spatial aspects of its growth patterns and processes are not rigorously researched until recently. Based on the recent studies that looked into its spatial growth patterns for significant periods of time (Dewan and Yamaguchi, 2009; Dewan et al., 2010; Ahmed et al., 2012), this research aims to extend that knowledge and evidence base. We aim to do it by exploring key spatial biophysical and socio-economic factors that can explain Dhaka's urban growth in recent decades, particularly since the late 1980s, as such growth was evident from the exploratory urban growth pattern analysis in Ahmed et al., 2012. This study further questions the strength of these factors to predict growth at meso scale (i.e. spatial planning zones), and simulates its growth in the near future (until 2025). By adopting a hybrid dynamic land-use modelling framework, this research, therefore, tries to provide key insights of urban growth pattern complexities captured under data-limited environments.

In subsequent sub-sections, after a brief review on recent introductions of Cellular Automata (CA) in urban growth models, the modelling framework is introduced; structure, modelling procedures, data requirements, and different modelling elements are also elaborated. The influence of different driving factors on the growth probabilities has been explored to examine their global and locally differentiated effects. Simulation has been attempted which is then calibrated and validated. Afterwards the validated parameters are used to simulate Dhaka into the near future (2015 and 2025) under a planning restriction scenario with two different sets of growth projections.

## 2. Cellular Automata in urban growth models

Different techniques or tools have been used to model LUCC in general and urban growth in particular. Recent advances in GIS technology, including greater availability of data through remote sensing, have brought cellular automata (CA)[4] techniques to the forefront in LUCC and urban growth modelling. Despite their apparently simple definition based on local rules, CAs can exhibit very complex dynamic behaviours, even in the case of the so-called elementary CAs, i.e. one-dimensional CA with two neighbours and two states. CA models are particularly robust at dealing with spatially related phenomena with finer resolutions. Being naturally 'bottom up', CAs can realistically mimic dynamic local-global relation in urban environments spatio-temporally with high-end visualisation (Batty and Xie, 1994; Torrens and O'Sullivan, 2001). The intrinsic ability of any CA models to allow dynamic local interaction amongst cells at each time step dispense them the added advantage of mimicking complex urban systems, thereby embedding several branches of complexity theories. For example, different areas in a city may exhibit self-organising local growth patterns due to dissimilar local actions, resulting in self-similar growth patterns or fractal dimensions across scales (ibid.). CA models have been employed in the exploration of a diverse range of urban phenomena like regional-scale urbanisation (Geertman et al., 2007) and Spatial Decision Support System (SDSS) (White et al., 2004), land-use dynamics (Almeida and

[2] Assuming population at 2015 as 15 million, this is a 20 year (1995–2015) strategy Plan for urban development within the Capital City Development Authority 's (RAJUK) jurisdiction. It consists of a report with supporting policy maps (Rajuk, 1997).

[3] Canals created naturally that pass through Dhaka City and used as drainage channels to drain out excess water from flood/heavy rain water to the surrounded outfall rivers. Begunbari khal, Dholai khal, Shegunbagicha khal, Tongi khal etc. are some major khals in Dhaka City (Tawhid, 2004).

[4] A classic cellular automata (CA) system consists of a regular grid of cells- each of which can be in one of a finite number of possible states, depending on the previous state of the cells within its defined neighbourhood; updated simultaneously at each discrete time step according to a set of transition rules (Batty and Xie, 1997, Torrens and O'Sullivan, 2001, Wagner, 1997, White and Engelen, 1993).