UNIVERSITI PUTRA MALAYSIA

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By

MOHAMED ABDULLAH AL-SHALABI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

I dedicate this work to my family – my great father, who supported me by financing me with the necessary amounts to buy satellite images and other related materials. To my mother, who supported me to a great extent with her prayers. My lovely brothers and sisters, my loyal wife and my cute kids ; Amani, Nora, Nada, Ayman, Norhan and my son Osama who suffered a lot in my absence– for their love, understanding, encouragement, and never failing support during all these years.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: **Professor Shattri Bin Mansor, PhD**

Faculty: **Engineering**

In this study, Sana'a master plans were evaluated and analyzed to verify whether their implementations corresponded with the actual spatial urban development. The result shows that until the present time there is still lack of clear policy that controls and guides urban development. It also shows that about 40% of the growth occurred in unplanned areas, green areas and reserved land without suitable protection and regulations.

GIS, remote sensing techniques and field survey were used to study the spatial pattern growth for the spontaneous areas in Sana'a city as well as the physical, socio-economic, and environmental conditions. There is no specific planning pattern was found in these settlements. Development has taken place randomly in unplanned areas, following the pattern of topography and concentrating along main roads.

The study has successfully developed a model for locating suitable land for urban development in Sana'a by integrating GIS and Multi-criteria Analysis and Cellular

Automata methods. The potential suitable lands were generated and the validation of the model was done by overlaying the generated suitability map on the potential land for residential development proposed by 1999 Sana'a master plan. The result shows the areas for future development proposed by the master plan corresponded well with the high to very high suitability zones except for illegal areas.

The prediction and simulation of the urban growth and land use change were done successfully in GIS-based CA model which output "managed growth scenario". Based on the land suitability assessment produced by the model, the demand for land for urban development during the period from 2004 to 2020 was then estimated using statistical tools. Then, the candidature of a cell by adopting again MCA method was evaluated. It provides dynamic transition rule for land use conversion at each time step of the simulation model based on the following factors used: land suitability, proximity to existing developed areas, proximity to prioritized land, and current land use. Variable calculation produces land use conversion probabilities for each cell. The rules are updated at each time step in order to reflect the land dynamics of the previous step. The result was validated through the process of running the model for the period from 1994 to 2003. The result gives an overall accuracy of 99.6%, producer's accuracy of 83.3% and the user's accuracy of 83.6%.

In this study the SLEUTH model was also used to predict the urban growth and land use change. It was calibrated using 35-year time series dataset compiled from interpreted historical topographical maps, aerial photographs and satellite imageries for the entire study area to identify the parameters that influenced the urban growth

in Sana'a city. Results from the calibration modes- coarse, fine, and final represented the top five scorings from thousands of iterations. The composite results of the optimum values for the diffusion, spread, slope and road gravity parameters show successive improvements in the parameters that control the behavior of the system. In the mechanism of self-modification rules, parameters averaging on the best results from the final calibration were used. The prediction mode of the SLEUTH model uses the best fit growth rule parameters from the calibration to begin the process of ''growing'' urban settlements, starting at the most recent urban data layer. The resulting forecast of future urban growth outputs a probability map where individual grid cells are being urbanized at some future date, assuming the same unique ''urban growth signature'' is still in effect as it was in the past. The final results of the model are annual layers map of future urban growth and land use change (2004–2020).

Based on the analysis the comparison between GIS-based CA model and SLEUTH model carried out and the strong and weak points of them were highlighted. This study benefits decision makers and planners in carrying out future urban growth planning and it gives them the opportunity to know the advantages and consequences for each growth scenario in order to promote the continuity and sustainability of urban development in the Sana'a city.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

RAMALAN DAN SIMULASI CORAK RUANG UNTUK PERTUMBUHAN PEMBANDARAN DAN PERUBAHAN DALAM GUNATANAH BAGI BANDARAYA SANA'A , YEMEN

Oleh

MOHAMED ABDULLAH AL-SHALABI

November, 2007

Pengerusi: **Profesor Shattri bin Mansor, PhD**

Fakulti: **Kejuruteraan**

Dalam kajian ini, pelan-pelan induk Sana'a telah di dinilai dan dinalisakan untuk menentukan samaada perlaksanaannya adalah sejejar dengan pembangunan ruang pembandaran yang sebenar berlaku. Kajian dapat menunjukkan bahawa setakat sekarang masih terdapat pula kekurangan polisi ketara yang mengawal dan memandu pembangunan pembandaran. Kajian menunjukkan juga bahawa kira-kira 40 % pertumbuhan berlaku pada kawasan yang tidak dirancang, kawasan hijau dan kawasan simpanan dengan tiada perlindungan dan peraturan yang sesuai.

Sistem Maklumat Geografi (GIS), penderiaan jauh dan kerja lapangan telah digunakan untuk mengkaji corak pertumbuhan ruang di kawasan penempatan spontan dalam bandaraya Sana'a, termasuk juga keadaan fizikal, sosio-ekonomi dan alam sekitar. Adalah didapati kawasan penempatan ini tiada corak perancangan spesifik. Pembangunan telah berlangsung secara rawak di kawasan-kawasan yang tidak dirancang, mengikuti corak topografi dan tertumpu pada jalan raya utama.

Kajian ini telah berjaya membangunkan sesuatu model untuk menentukan lokasi kawasan yang sesuai bagi tujuan pembangunan pembandaran di Sana'a dengan menggunakan GIS, Analisa Pelbagai Kriteria (MCA) dan Cellular Automata Methods. Peta kawasan berpotensi sesuai telah dihasilkan dan pengesahan model dapat dijalankan dengan penindihan peta ini ke atas peta kawasan potensi pembangunan perumahan yang dicadangkan dalam Pelan Induk Sana'a tahun 1999. Hasil pertindihan ini menunjukkan bahawa kawasan-kawasan yang disyorkan dalam pelan induk untuk pembangunan masa depan terjatuh pada zon-zon sesuai ke sangat sesuai kecuali kawasan penempatan haram.

Ramalan dan simulasi pertumbuhan pembandaran dan perubahan gunatanah telah dijalankan dengan jayanya dengan penggunaan model CA berasaskan GIS, yang dapat menghasilkan "senario pertumbuhan yang diurus". Berasaskan penilaian kesesuaian tanah yang dihasilkan oleh model, permintaan tanah pembandaran bagi tempoh 2004-2020 dapat dianggarkan dengan penggunaan kaedah statistik. Kemudian calonan sel dapat dinilai dengan penggunaan MCA sekali lagi. Ia telah memberikan satu peraturan perubahan dinamik untuk penukaran gunatanah pada setiap langkah masa model simulasi berasaskan faktur-faktur berikut : kesesuaian tanah, kedekatan kepada kawasan yang telah dibangun, kedekatan kepada kawasan keutamaan dan gunatanah semasa. Perkiraan angkubah menghasilkan kebarangkalian perubahan gunatanah bagi setiap sel. Peraturan-peraturan dikemaskinikan bagi setiap langkah masa untuk mencerminkan status dinamik tanah bagi langkah yang lalu. Keputusan ini dapat disahkan melalui proses pengoperasian model bagi tempoh dari

tahun 1994 ke tahun 2003. Ia telah memberikan ketepatan menyeluruh 99.6%, ketepatan pengeluar 82.6% dan ketepatan pengguna 82.2%.

Dalam kajian ini model SLUETH telah diguanakan juga unutk meramalkan pertumbuhan pembandaran dan perubahan gunatanah. Kalibrasi model dapat dijalankan dengan penggunaan data yang dikumpulkan selama 35 tahun daripada peta topografi yang lalu, gambar foto udara dan data satelit bagi seluruh kawasan kajian untuk mengenalpasti faktur-faktur yang mengpengaruhi pertumbuhan pembandaran Sana'a. Keputusan daripada mod-mod kalibrasi, iaitu, kasar, halus dan akhir, mewakili lima markah tertinggi dari beberapa ribu ulangan. Keputusan gabungan nilai–nilai optima daripada parameter-parameter penyerapan, pengedaran, kecerunan dan graviti jalan menunjukkan peningkatan berterusan kawalan parameter terhadap kelakuan sistem. Dalam mekanisma aturan ubahsuaian-sendiri purata parameter berasaskan keputusan terbaik daripada proses kalibrasi terakhir digunakan. Mod ramalan model SLUETH menggunakan parameter-parameter aturan pembangunan paling padan dari kalibrasi untuk memulakan proses "pertumbuhan" penempatan pembandaran, mulai dari data pembandaran yang terkini. Hasil ramalan pertumbuhan pembandaran masa depan adalah peta kebarangkalianyang mana setiap sel grid mempunyai nilai kebarangkalian pembandaran masa depan dengan andaian "tandatangan pertumbuhan pembandaran" yang khas ini adalah sama seperti dalam tahun-tahun lalu. Keputusan terakhir model merupakan peta-peta tahunan pertumbuhan pembandaran dan perubahan gunatanah masa depan (2004-2020).

Berasaskan analisa yang dijalankan, kelebihan dan kekurangan model–model yang digunakan dapat diutarakan. Kajian ini memanfaatkan pembuat-pembuat keputusan dan perancang-perancang perancangan pertumbuhan pembandaran masa depan dan memberi kesempatan untuk mengetahui kebaikan serta akibat setiap senario pertumbuhan supaya dapat mempromosi keterusan dan kelestarian pertumbuhan pembandaran di bandaraya Sana'a.

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All praise to **Allah,** most Gracious, Most Merciful, Who, Alone brings forgiveness and light and new life to those who call upon Him; and to Him is the dedication of this thesis.

"Read! In the Name of your Lord Who has created (all that exist).
He has created man from a clot.
Read! And your Lord as the Most Generous.
Who has taught (the writing) by the pen.
He has taught man that which he knew not."
Qur'an 96: 1-5

We praise Allah for His great loving kindness, which has brought us all together to tell and encourage each other and mankind with stories of His care, and leading. In so doing, I also thank those who answered His call, who have started their journey upon the Straight Path of Allah. All respect for our Holy Prophet (Peace be upon him), who guided us to identify our creator

I am whole-heartedly thankful to my research supervisor, Prof. Dr. Shattri bin Mansor for his encouragement, exceptional ideas, and tireless optimism that have kept me going. Without his guidance, this work wouldn't see the light. He has exerted a lot of efforts and lighted the dark for me.

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I certify that an Examination Committee has met on to conduct the final examination of Mohamed Abdullah Saleh Al-Shalabi on his Doctor of Philosophy thesis entitled "PREDICTION AND SIMULATION OF SPATIAL PATTERN FOR URBAN GROWTH AND LAND USE CHANGE OF SANA'A CITY, YEMEN" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Universiti Putra Malaysia

Date: 10 April 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any degree at UPM or other institutions.

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MOHAMED ABDULLAH AL-SHALABI

Date:

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Cities or urban areas are the symbol of modernization. Urban activities are the wheel of a country's economy. The city is a magnet; it is a home and recreational center for city residents; it is a market place and shopping center for rural dwellers; it offers work and job opportunities to the unemployed and criminals; it is a source of souvenirs for tourists, visitors and foreigners. If it is a capital, major national policies are made and decisions are taken there; it is the home of major financial and economic institutes; it is a transportation hub. On the other hand cities are the source of complex problems. They need special attention from the whole fabric of society, particularly urban planners and decision-makers, who are responsible for the planning and management of the cities.

Urban areas comprise a relatively small portion of the earth's surface, but it is a major type of land use and land cover change in the human history and contains a disproportionate share of the earth's total population. The United Nations (2004) estimated that nearly half of the world's population lived and worked in urban areas. In addition to population pressure, urban areas are subjected to intensive usage from industrial production, commercial developments, and transportation and communication infrastructure. Such intense land usage often translates into social and environmental impacts that extend well beyond the spatial limits of the city itself.