



UNIVERSITI PUTRA MALAYSIA

***MODELLING RAPID URBAN GROWTH OF KIRKUK CITY BASED ON
ETHNICITY FACTORS USING
GIS AND CELLULAR AUTOMATA-MARKOV***

MAZEN ABDILWAHAB ABDULA

FRSB 2016 13



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By

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

November 2016

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DEDICATION

I would like to dedicate this thesis to:

My parents, who would have appreciated seeing it if they were still alive.

To my family

Brothers and Sisters

All loyal friends



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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November 2016

Chairman : Mohd Johari Mohd Yusof, PhD
Faculty : Design and Architecture

During the past 90 years, Kirkuk City has grown rapidly due to the exploitation of its oil reserves. As a multi-ethnic city, the presence of oil has been a source of ethnic conflict among the Kurds, Arabs and Turkmen. Kirkuk has long been considered an ethnic powder keg waiting to explode. Each group's own distinctive historical narrative became increasingly politicised and antagonistic during the twentieth century. The Iraqi Government implemented an aggressive and extensive social engineering policy designed to manage potential political and security threats to the oilfields that had been established in Kirkuk. A new social policy of Arabisation was implemented; a preferential treatment policy which favoured the ethnic Arabs over non-Arabs.

However, while the ethnic Arabs benefitted from the affirmative action policy, the other ethnicities were expelled and this led to rising ethnic tension; planting a seed of antagonism towards ethnic Arabs and led to negative social relations between ethnic groups, which was augmented by residential segregation that divided the three major ethnic groups further.

Following the invasion of Iraq in 2003, the Kurds have become more politically powerful and an importuned force in the politics of the state, which in turn is even more important than the demographic issues in the powerful symbol of Kirkuk. As a reaction, another demographic change has occurred with informal rapid urban growth represented by many Kurdish returnees following the new Kurd government policy of Kurdification. The demographic change is a layered and multi-faceted social interaction that in many ways makes the resolution of Kirkuk's ethno-political tension difficult to achieve, particularly when this complex picture is coloured by the presence of immense quantities of oil reserves. This thesis used GIS and CA- Markov to examine Kirkuk City's urban growth, the factors that influenced its development, the impact of socio-political conflict represented by ethnic conflict on urban growth, the reshaping of the Master Plan and the pattern of settlement development of the city.

A model was developed to simulate the residential expansion based on ethno-political conflict areas for each ethnic group in order to answer the question: “Dose political transition based on ethnicity affect the shape of a city master plan?”. The findings of the study suggested that there are significant effects of ethno-political factors in urban growth and planning, as well as future trends. However, the effect of the other physical, environmental and socio economic factors were not strong as a determinant of social interaction and integration, and other non-spatial factors were more important. The ethno-political factors shaped the city’s Master Plan toward the north-eastern side of the city even though it was not recommended in the previous Master Plan. The findings visualised the shape of the future Master Plan based on ethnicity. According to all the above-mentioned factors, if the status of Kirkuk governorate is not settled politically, Kirkuk City’s planning pattern will continue to be heterogeneous. The findings have important policy implications to avoid the segregation of the society of Kirkuk City and will assist policy makers and urban planners to consider the trends in urban growth expansion and give the advantages and consequences for each ethnic scenario.

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

**PEMODELAN PERKEMBANGAN KAWASAN BANDAR DI BANDAR
KIRKUK BERDASARKAN FAKTOR ETNIK MENGGUNAKAN
GIS DAN CELLULAR AUTOMATA-MARKOV**

Oleh

MAZEN ABDILWAHAB ABDULA

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Dalam tempoh 90 puluh tahun ini, Bandar Kirkuk telah berkembang dengan pesat disebabkan eksploitasi rizab minyak. Sebagai sebuah bandar multi-etnik, penemuan minyak telah menjadi sebab berlakunya konflik etnik dalam kalangan orang Kurd, Arab dan Turkmen. Kirkuk telah lama dianggap sebagai kawasan campuran pelbagai etnik yang akan mencetus perkelahian. Sejarah setiap kumpulan etnik ini telah dipolitikkan dan diapikan semasa abad ke-20. Kerajaan Iraq telah melaksanakan dasar pengendalian sosial yang agresif dan meluas yang bertujuan untuk membendung kemungkinan ancaman berbentuk politik dan ancaman keselamatan kepada telaga minyak yang telah ditubuhkan di Kirkuk. Polisi sosial baru peng-Arab-an telah dilaksanakan; polisi pilih kasih yang melebihkan kepentingan orang Arab etnik berbanding kepentingan etnik bukan Arab.

Walau bagaimanapun, semasa orang Arab etnik mendapat kelebihan daripada polisi tindakan afirmatif itu, etnik-etnik lain telah diusir dan ini membawa kepada meningkatnya ketegangan hubungan etnik; menanam benih permusuhan terhadap orang Arab etnik dan membawa kepada hubungan sosial yang negatif antara kumpulan-kumpulan etnik yang bertambah lagi disebabkan oleh pengasingan kawasan kediaman yang membahagikan tiga kumpulan etnik utama itu.

Berikutan serangan ke atas Iraq pada tahun 2003, Orang Kurd telah mendapat kuasa politik yang lebih kuat dan mempunyai kuasa mendesak dalam politik negara ini, isu ini menjadi lebih penting daripada isu demografi dalam simbol kekuasaan Kirkuk. Berikutan ini, satu lagi perubahan demografi telah berlaku iaitu pertumbuhan bandar tidak rasmi yang pesat disebabkan kepulangan orang Kurd berikutan polisi baru peng-Kurd-an oleh kerajaan Kurd. Perubahan demografi ini adalah interaksi sosial yang berlapis dan berbagai yang, dalam banyak cara, membuatkan resolusi ketegangan etno-politik di Kirkuk sukar dicapai, terutamanya bila gambaran kompleks ini ditambah lagi dengan kehadiran rizab minyak yang mewah. Tesis ini menggunakan GIS dan CA- Markov untuk memeriksa perkembangan Bandar Kirkuk; faktor-faktor

yang mempengaruhi perkembangannya; kesan konflik sosio-politik, yang diwakili oleh konflik etnik, ke atas perkembangan bandar; pembentukan semula Pelan Induk; dan corak penempatan pembangunan bandar ini. Satu model telah dibina menggunakan ca-markov sebagai simulasi perkembangan kawasan kediaman berdasarkan kawasan konflik etno-politik untuk setiap kumpulan etnik untuk menjawab soalan berikut: “Adakah Peralihan Politik Yang Berdasarkan Etnik Akan Memberi Kesan Kepada Bentuk Pelan Induk Sesebuah Bandar?” Hasil kajian menunjukkan kemungkinan yang faktor etno-politik memberikan kesan yang besar untuk perkembangan dan perancangan bandar, termasuklah trend masa depan. Walau bagaimanapun, kesan daripada faktor fizikal, persekitaran, dan sosio-ekonomi adalah tidak sekuat sebagai penentu interaksi sosial dan integrasi, dan faktor bukan-ruang adalah lebih penting. Faktor etno-politik membentuk Pelan Induk kawasan Timur Laut bandar walaupun ini tidak digalakkan dalam Pelan Induk sebelum ini. Penemuan ini menggambarkan bentuk Pelan Induk masa hadapan yang berdasarkan etnik. Menurut semua faktor yang disebut di atas, jika status pentadbiran Kirkuk tidak dapat diselesaikan secara politik, corak perancangan Bandar Kirkuk akan terus dipengaruhi kebudayaan beraneka ragam. Hasil kajian mempunyai implikasi polisi yang penting untuk mengelakkan pengasingan masyarakat di Bandar Kirkuk, dan akan membantu pembuat dasar dan perancang bandar untuk mempertimbangkan trend perkembangan bandar dan menunjukkan kelebihan dan konsekuensi untuk setiap senario etnik.

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I certify that a Thesis Examination Committee has met on 28 November 2016 to conduct the final examination of Mazen Abdilwahab Abdula on her thesis entitled "Modelling Rapid Urban Growth of Kirkuk City Based on Ethnicity Factors using GIS and Cellular Automata-Markov" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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TABLE OF CONTENTS

| | Page |
|---|-------------|
| ABSTRACT | i |
| ABSTRAK | iii |
| ACKNOWLEDGEMENTS | v |
| APPROVAL | vi |
| DECLARATION | viii |
| LIST OF TABLES | xiv |
| LIST OF FIGURES | xvi |
| LIST OF ABBREVIATIONS | xix |
| | |
| CHAPTER | |
| 1 | |
| INTROCUCTION | 1 |
| 1.1 Background of Study | 1 |
| 1.2 Problem Statement | 3 |
| 1.3 Research Questions | 6 |
| 1.4 Research Objectives | 6 |
| 1.5 Significance of the Study | 6 |
| 1.6 Scope of the Research | 7 |
| 1.7 Outline of the Thesis | 7 |
| | |
| 2 | |
| LITERATURE REVIEW | 9 |
| 2.1 Developing Countries and Urbanisation | 9 |
| 2.1.1 Pull and Push Factors | 10 |
| 2.2 Urbanisation and Urban Growth | 10 |
| 2.2.1 Sprawl | 12 |
| 2.2.2 Definitions of “Sprawl” | 13 |
| 2.2.3 Leapfrog Development | 13 |
| 2.2.4 Strip or Ribbon Development | 14 |
| 2.2.5 Low Density, Single Dimensional Development | 14 |
| 2.2.6 Causes of Sprawl | 14 |
| 2.2.7 Sprawl Impacts | 15 |
| 2.3 Informality | 15 |
| 2.3.1 Informal housing | 16 |
| 2.3.2 Slums | 17 |
| 2.4 Ethnic Identity | 18 |
| 2.4.1 Categories of Ethnicity | 19 |
| 2.4.2 Definition of Comparative Ethnic Identity | 20 |
| 2.4.3 Urban Ethno-Political Conflict | 20 |
| 2.4.4 Types of Cities | 21 |
| 2.4.5 Urban ethnic conditions | 23 |
| 2.5 Ethnicity Background In Kirkuk City | 25 |
| 2.5.1 Pre-Arabization growth of Kirkuk | 25 |
| 2.5.2 The Arabization Policy | 26 |
| 2.5.3 Intensified Violence | 28 |
| 2.5.4 Kurdification | 30 |
| 2.6 Urban Condition in Iraq | 31 |

| | | |
|----------|--|-----------|
| 2.6.1 | Informality and Spontaneous Settlements Based on Ethnicity in Kirkuk | 33 |
| 2.6.2 | Factors That Influence the Increase of Spontaneous Settlements | 34 |
| 2.7 | Modelling Urban Growth | 34 |
| 2.7.1 | About Models | 35 |
| 2.7.2 | Urban Growth Models | 37 |
| 2.7.3 | Cellular Automata-based Models | 39 |
| 2.7.4 | GIS and Cellular Automata Model | 43 |
| 2.7.5 | Multi-Criterion Evaluation Model | 43 |
| 2.7.6 | Multi-Criterion Evaluation Technique in Cellular Automata Model | 45 |
| 2.7.7 | Model Selection | 48 |
| 2.7.8 | Markov Chain Model | 49 |
| 2.7.9 | Markov Chain Analysis | 50 |
| 2.7.10 | CA-Markov Modelling of Land-use Change | 51 |
| 2.8 | Simulation Trends of Land-change by CA-Markov | 53 |
| 2.9 | Validation | 56 |
| 2.10 | Summary | 57 |
| 3 | DATA AND METHODOLOGY | 59 |
| 3.1 | Introduction | 59 |
| 3.2 | Study Area | 61 |
| 3.2.1 | Historical Overview of Kirkuk | 61 |
| 3.2.2 | Geography of Kirkuk | 61 |
| 3.2.3 | Natural Attributes | 62 |
| 3.2.4 | Manmade Obstacles (Artificial) | 62 |
| 3.3 | Population of Kirkuk | 64 |
| 3.4 | Kirkuk Master Plan | 67 |
| 3.5 | Collection and Processing of Dataset and Materials | 69 |
| 3.5.1 | Primary Dataset | 69 |
| 3.5.2 | Secondary Datasets and Tools | 74 |
| 3.5.3 | Processing Tools and Software | 74 |
| 3.6 | Pre-processing Database | 74 |
| 3.6.1 | Base Map Preparation | 75 |
| 3.6.2 | Preparation of Data based GIS | 75 |
| 3.7 | Specification of Parameters (Identifying Criteria) | 75 |
| 3.7.1 | Population Density | 76 |
| 3.7.2 | Built up Areas | 79 |
| 3.7.3 | Slope | 81 |
| 3.7.4 | Income | 83 |
| 3.7.5 | Land value | 83 |
| 3.7.6 | Road network | 84 |
| 3.7.7 | River | 86 |
| 3.7.8 | Ethnic Composition of the Population | 86 |
| 3.7.9 | Security Issues | 91 |
| 3.8 | Constraint Development | 95 |
| 3.9 | Criterion Weights | 95 |
| 3.9.1 | Multiple Criteria Evaluation Models | 96 |
| 3.9.2 | Method of Calculating Weights | 97 |

| | | |
|----------|--|------------|
| 3.9.3 | Evaluating the Relative Importance of Each Criterion vs Other Criteria | 97 |
| 3.9.4 | Ranking and Rating Methods | 99 |
| 3.9.5 | Normalisation | 101 |
| 3.9.6 | Standardisation Method | 101 |
| 3.10 | Constraint map in GIS-MCE | 102 |
| 3.10.1 | Military Zone and National Oil Area | 102 |
| 3.10.2 | Water Bodies | 103 |
| 3.10.3 | Ethnic Group Neighbourhood | 103 |
| 3.11 | Satellite imagery and Pre-processing | 103 |
| 3.11.1 | Geo-referencing | 103 |
| 3.11.2 | Study area clip | 103 |
| 3.11.3 | Classification | 104 |
| 3.11.4 | Accuracy Assessment | 107 |
| 3.11.5 | Image Resampling and Reclassification of Geometric Correction | 113 |
| 3.12 | Model Approach | 114 |
| 3.12.1 | Processing and Design | 115 |
| 3.12.2 | Integrating GIS and CA for Urban Dynamics Modelling | 116 |
| 3.13 | Suitability Image Collection in CA-Markov Land-change Modelling | 116 |
| 3.13.1 | Preparation of the Suitability Maps Based on Ethnic Groups | 117 |
| 3.14 | Cellular Automata and Markov Chain Model | 118 |
| 3.14.1 | CA-MARKOV Model | 119 |
| 3.15 | Uncertainty and Validation | 121 |
| 3.16 | Summary | 122 |
| 4 | RESULTS AND DISCUSSION | 123 |
| 4.1 | Introduction | 123 |
| 4.2 | Questionnaires and Interviews | 123 |
| 4.2.1 | Criteria Influencing Urban Development | 123 |
| 4.2.2 | Weighting Criteria by Pairwise Comparison | 124 |
| 4.3 | Land Development and Change Detection | 125 |
| 4.3.1 | Classification | 127 |
| 4.4 | Distribution Analysis of Land-use Changes | 129 |
| 4.5 | Peripheral Expansion of Kirkuk City | 131 |
| 4.6 | The Result of Informal and Spontaneous Settlements | 132 |
| 4.7 | Interpretation and Analysis Stage | 134 |
| 4.7.1 | Suitability Maps Analysis | 135 |
| 4.7.2 | Integration GIS and Markov-Cellular Automata (CA) | 143 |
| 4.8 | The First Run of the CA-Markov Model | 145 |
| 4.8.1 | Comparison Based on Ethnicity | 150 |
| 4.9 | Urban Growth Prediction | 156 |
| 4.10 | Model Validation and Goodness of Fit of Map Simulation | 158 |
| 4.11 | Summary | 159 |

| | | |
|----------|---|-----|
| 5 | CONCLUSIONS AND RECOMMENDATIONS | 161 |
| 5.1 | Introduction | 161 |
| 5.2 | Discussion and Conclusions | 161 |
| 5.3 | Theoretical and Technical Implications For Planning in Kirkuk City | 164 |
| 5.4 | Future of Kirkuk. | 168 |
| 5.5 | Recommendations and Future Studies | 170 |
| 5.6 | Research Limitation and Justification | 171 |
| | REFERENCES | 173 |
| | APPENDICES | 189 |
| | BIODATA OF STUDENT | 211 |
| | LIST OF PUBLICATIONS | 212 |



LIST OF TABLES

| Table | Page |
|---|------|
| 2.1 National population (Nations, 2010) | 12 |
| 2.2 Commonly-used methods of multi-criteria weighting | 44 |
| 2.3 Markovian transition probability matrix | 51 |
| 2.4 Analyses of Markov-CA-MCE Models in Urbanisation | 55 |
| 3.1 Population Growth Rate of Kirkuk and Iraq | 64 |
| 3.2 Projected Kirkuk population (1975 – 2000) | 64 |
| 3.3 Population Estimates for Kirkuk Province after 2003 | 66 |
| 3.4 Factors Affecting Urban Expansion | 70 |
| 3.5 Census 1957 Reflecting the Ethnic Mix | 86 |
| 3.6 Comparison Of Ethnicity In Kirkuk | 87 |
| 3.7 Pairwise comparison matrix AHP | 96 |
| 3.8 Scale of evaluation AHP | 98 |
| 3.9 Steps in generating IDRISI format files from other formats | 113 |
| 4.1 Factors Scores Affecting Urban Development | 124 |
| 4.2 The Area of Classes in LANDSAT Images (1984, 2000 and 2013) | 131 |
| 4.3 Markov transition area 1984-2000 for Arab ethnicity | 144 |
| 4.4 Markov transition area 2000-2013 for Arab ethnicity | 144 |
| 4.5 Markov transition area 1984-2000 for Kurd ethnicity | 144 |
| 4.6 Markov transition area 2000-2013 for Kurd ethnicity | 144 |
| 4.7 Markov transition area 1984-2000 for Turk ethnicity | 145 |
| 4.8 Markov transition area 200-2013 for Turk ethnicity | 145 |
| 4.9 Class Areas in Predictive Years 2016-2026 for Arab ethnicity | 156 |
| 4.10 Class areas in predictive years 2016-2026 for Kurd ethnicity | 157 |

| | | |
|------|--|-----|
| 4.11 | Class areas in predictive years 2016-2026 for Turk ethnicity | 157 |
| 4.12 | Validation results by Kappa index for year 2016 | 158 |
| 4.13 | Validation results by Kappa index for year 2026 Future Scenarios of Kirkuk City | 159 |
| 5.1 | Future Scenarios of Kirkuk City | 169 |



LIST OF FIGURES

| Figure | Page |
|---|------|
| 2.1 Cities with local democratic management during major transitions associated with regime change or post-war reconciliation and reconstruction (source www.crisisgroup.org) | 23 |
| 2.2 The Shortfall of Housing Units in Iraq | 33 |
| 2.3 Model Process (Wegener, 2004) | 37 |
| 3.1 Model Procedure | 60 |
| 3.2 Map Showing the Location of Kirkuk City | 63 |
| 3.3 Population (based on International/Doxiadis, 1975) | 65 |
| 3.4 Population of The City (Kirkuk Provincial Government, 2007) | 66 |
| 3.5 Boundary of the Study Area | 68 |
| 3.6 A City Plan of Kirkuk by US Corps of Engineers, August 2006 | 71 |
| 3.7 Doxiadis Master Plan (1975) | 72 |
| 3.8 Available Hard Copy of Kirkuk Master Plan | 73 |
| 3.9 Population Density For Years 1984, 2000, 2013 | 78 |
| 3.10 Built Up Areas For Years 1984, 2000, and 2013 | 80 |
| 3.11 Slope of the City and Study Area Extracted from DEM | 82 |
| 3.12 Road Network Within The Study Area | 85 |
| 3.13 Ethnicity growth from 1957 to 1997 | 87 |
| 3.14 Ilustration Of Internally Displaced Persons And Ethnicity In Kirkuk City. (M. Knights & Ali, 2010) | 89 |
| 3.15 Ethnic Distribution Of Kirkuk City | 90 |
| 3.16 Security area in Kirkuk city | 92 |
| 3.17 Security Area in Kirkuk City Environmentally Sensitive Areas | 93 |
| 3.18 Environmentally Sensitive Area (ESA) | 94 |

| | | |
|------|--|-----|
| 3.19 | Image classification procedure | 105 |
| 3.20 | LANDSAT Images for Years 1984, 2000 and 2013 | 109 |
| 3.21 | Land-Use and Land-Cover Classification for year1984 | 110 |
| 3.22 | Land-Use and Land-Cover Classification for year2000 | 111 |
| 3.23 | Land-Use and Land-Cover Classification for year2013 | 112 |
| 3.24 | Overview of Model | 114 |
| 3.25 | Process Of Suitability Map Based On Ethnic Distribution | 118 |
| 3.26 | Processes of Urban Simulation Image 2000 is the base image | 120 |
| 3.27 | Processes of Urban Simulation Image 2013 is the base image | 121 |
| 4.1 | LANDSAT Images Of Study Area For Years 1984, 2000 and 2013 | 126 |
| 4.2 | Classified LANDSAT Images Of Study Area Illustrating The Actual Expansion For Years 1984, 2000 and 2013 | 128 |
| 4.3 | Proposed Master Plan of Kirkuk City | 133 |
| 4.4 | Land Suitability Maps for Arab Ethnicity Group for Year 2000 | 137 |
| 4.5 | Land Suitability Maps for Turk Ethnicity Group for Year 2000 | 138 |
| 4.6 | Land Suitability Maps for Kurd Ethnicity Group for Year 2000 | 139 |
| 4.7 | Land Suitability Maps for Arab Ethnicity Group for Year 2013 | 140 |
| 4.8 | Land Suitability Maps for Turk Ethnicity Group for Year 2013 | 141 |
| 4.9 | Land Suitability Maps for Kurd Ethnicity Group for Year 2013 | 142 |
| 4.10 | (a) Classified actual LANDSAT image 2000 (b) Projected image 2016 for Arab ethnicity (c) Classified actual LANDSAT image 2013 | 147 |
| 4.11 | (a) Classified actual LANDSAT image 2000 (b) Projected image 2016 for Kurd ethnicity (c) Classified actual LANDSAT image 2013 | 148 |
| 4.12 | (a) Classified actual LANDSAT image 2000 (b) Projected image 2016 for Turk ethnicity (c) Classified actual LANDSAT image 2013 | 149 |
| 4.13 | (A) Simulation of Urban Expansion Based on Arab Ethnicity 2016 (B) Simulation of Urban Expansion Based on Turk Ethnicity 2016 | 152 |
| 4.14 | (C) Simulation of Urban Expansion Based on Kurd Ethnicity 2016 | 153 |

| | | |
|------|--|-----|
| 4.15 | (A) Simulation of Urban Expansion Based on Arab Ethnicity 2026(B) Simulation of Urban Expansion Based on Turk Ethnicity 2026 | 154 |
| 4.16 | (C) Simulation of Urban Expansion Based on Kurd Ethnicity 2026 | 155 |



LIST OF ABBREVIATIONS

| | |
|------|--------------------------------------|
| KPC | Kirkuk Province Council |
| DEM | Digital Elevation Model |
| CA | Cellular Automata |
| IDPs | Internal Displaced Persons |
| MCE | Multi-Criteria Evaluation |
| GIS | Geographical Information System |
| RS | Remote Sensing |
| MCET | Multi-Criteria Evaluation Technology |
| ILO | International Labour Organisation |
| MDGs | Millennium Development Goals |
| EGM | Expert Group Meeting |
| LU | Land Use |
| AHP | Analytic Hierarchy Process |
| PSS | Planning Support System |
| MOLA | Multi-Objective Land Allocation |
| WLC | Weighted Linear Combination |
| RC | Ratio Consistency |
| TM | Thematic Mapper |
| ETM | Enhance Thematic Mapper |
| USGS | United States Geological Survey |
| SRTM | Shuttle Radar Topography Mission |
| EROS | Earth Resources Observation Systems |
| DTED | Digital Terrain Elevation Data |
| UTM | Universal Transverse Mercator |
| GCS | Geographic Coordinate System |
| ESA | Environmental Sensitive Area |
| MLC | Maximum Likelihood Classification |
| DN | Digital Number |

| | |
|-------|--|
| ASCII | American Standard Code for Information Interchange |
| RMS | Root Mean Squared RMS |
| RGF | Raster Group files |
| FCUS | Future Conceptual Urban Structure (FCUS) |



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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Several problems and issues have developed from the recently experienced political, economic and demographic changes; these changes are totally different from those of the past. The structures and sizes of numerous cities around the world have been changed due to demographic changes, with suburban areas experiencing environmental and social problems which previously only affected urban areas.

There is a relationship between political, economic and historical circumstances with regards to urban reality and the problems surrounding it. This reality is seen at varying levels in both developed and under developed societies of the world. However, these relationships and differences prove that urban problems have their causes and as such, urban development is a result of the interactions between urban problems and these relationships and differences. Urban development is the intricate net which consists of environmental, human, social, economic and administrative problems. Just like any other process, the factors that influence urban change are related to the appearance in urbanisation. As a reaction, the relationship between these factors has resulted in many constructional, residential and planning problems.

According to Weber and Puissant (2003), the standard of living of urban dwellers has been lowered as a result of rapid global urbanisation. The increase of urban populations can be linked to globalisation even though this urbanisation is experienced at different levels across countries around the world. It is projected that the transformation in population size and spatial distribution will continue to grow in the future because of unending urbanisation and increases in population size; with this, it is predicted that the global urban population will rise in the future to 2.5 billion by 2050, especially in Asia and Africa. Also, another report by the United Nations (2014), projected global urban growth to increase by 66%. By 2050, this will amount to a world urban population of 6.4 billion out of 8.9 billion total world population. This implies that only 2.5 billion of the world population will not be living in urban areas (World Urbanisation Prospects 2005, 2006 and 2007; Revised 2008; Revised 2012). This increase in urban population according to the United Nations is caused by rural-urban migration, which in turn results in a change of natural land for urban use caused by spatial distribution of human settlements (United Nations, 2014).

Some of the negative impacts of such rapid urban growth are motorised transport, increased rate of energy consumption, pollution (noise, air and water), relative loss of rich agricultural land, and damaged or destroyed biological ecosystem diversity. Even though researchers and policy makers view this negative impact as a symbol that shows the economic strength of the affected region, they also view it as a sign of

environmental and ecological degradation. Thus, it is important for the stakeholders in this field of study to take note of the changes caused by urban dynamics so as to know how to plan and manage the situation (Knox, 1993; Turner et al., 1993).

Other negative impacts include ethnic conflict, an important determinant of the political, economic and social development of many nations and localities. It is widely believed that ethnic conflict leads to political instability, poor quality of institutions, badly designed economic policy and disappointing economic performance, all of which, in one way or another, impact the urban development and the lifestyle of the population. (Alesina, Devleeschauwer, Easterly, & Kurlat, 2003)

In related literature, early examples such as Canning and Fay (1993) and Mauro (1995), have discussed the effects of ethnic fragmentation on government activities and quality of institutions. La Porta et al. (1999), in a broad empirical study of the determinants of the quality of government, are of the opinion that ethnic fractionalisation matters, even though variables related to legal origins may be more important. There is ample literature indicating that in more ethnically fragmented communities, the provision of public goods is less efficient, participation in social activities and trust is lower, and economic success, measured by growth of city size, falls short of expectations. Evidence that trust does not travel well across racial lines is also supported by Glaeser, Laibson, Scheinkman, & Soutter (2000) and Alesina, Devleeschauwer, Easterly & Kurlat (2003).

Multi-temporal images can be used to see continuous urban growth especially in cases where undeveloped areas convert to partly developed, and then to fully developed, within a given period of time. The common process of urbanisation is expansion from downtown to suburbs and gradually to urban areas with different rates of growth in various directions. Some areas experience directional growth compared to other locations due to popular attractions found within the areas (Al-Kheder, 2006).

There are major urban growth factors that determine the process of urbanisation and expansion are physical, environmental and socio-economic factors (Clarke, 1997). Every geometric attribute which directly affects the process of development in a negative or positive way is referred to as a physical variable. One possible factor could be elevation, highlighted using a Digital Elevation Model (DEM) alongside the structure of land use.

Socio-economic factors are the second category that affects urban growth such as population distribution. The greater the distance from a city centre to the suburbs, the lesser the growth of the population. Another factor which mainly affects infrastructures such as road networks is often affected by origin-destination trip behaviours of travellers. Other socio-economic factors include crime rates, population density, income level, political aspects and ethnic diversity (Al-Kheder, 2006). The intricate nature of the process of urban growth is greatly affected by these growth factors.

Researchers have continued to show growing interest in modelling the process of urbanisation with a specific focus on examining the dynamics of intricate urban systems and investigating how the environment and lifestyle are affected by urban growth. In order to implement realistic dynamic modelling, there is a need to use ample techniques and methodologies of urban modelling. For this reason, there are some analytical models that have been designed based on the physical attributes of a city and the relationship between city size, economic status, and ethnic distribution (Yang & Lo, 2003).

The main function of these models is to facilitate the understanding of urban growth and the pattern of this growth based on ethnicity, rather than to project urban development that may occur in the future (Yang & Lo, 2003). In recent times, new intelligent techniques of urban modelling have been developed due to various reasons. Firstly, intelligent models enhance interpretation which mathematical models are unable to do because they are developed through the use of simple and understandable rules of transition. Secondly, intelligent models are more suitable for urban modelling because the spatial nature of an urban modelling process contains a two-dimensional grid derived from imagery alongside its related factors; hence urban growth can be fitted into these intelligent models. An example is the Cellular Automata (CA) model which is well-suited to such a process. Thirdly, intelligent models are a better option because they enhance visualisation more effectively than conventional urban models, thereby reducing modelling errors while enhancing urban modelling efficiency. The introduction of these intelligent models facilitates the understanding of the spatial effect of urban growth through the use of dynamic modelling techniques as well as detecting temporal variations (Allen & Lu, 2003). Cellular Automata-based intelligent models are designed to simplify the intricate process of urbanisation while maintaining accuracy.

The use of intelligent techniques and automata-based intelligent models provide the framework for the discovery of cross-cutting policy issues that bridge different types of cities, or cities at a particular location on the analytical continuum. The distillation of such insights broadens the relevance of this research for practitioners and policy-makers. The key urban ethnic conditions that are affected by planning policies can be visualised and described in terms of how they may facilitate or impede the movement towards peaceful co-existence between all ethnic groups.

1.2 Problem Statement

The main problem is the constant change in Iraq's urban development situation which is reminiscent of the experiences in other developing countries. This problem is not improving due to constant wars and economic and political instability that have been experienced in Iraq over the past three decades. The effects of these problems are seen in the living standards and intellectual and cultural changes occurring in Iraq. There are additional obstacles associated with planning caused by natural and man-made demographic factors. One serious problem is the emergence of illegal urban growth based on ethnicity caused by the racial policy of the previous government. This policy

saw unorganised city growth and the failure of Kirkuk City's Master Plan to meet the development needs of the rapidly growing population.

Political transition that has led to difficult living conditions is one of the causes of unrestrained urban sprawl in the city, which in turn continues to cause environmental and socio-economic problems, one of which is the growing tension between the ethnic groups. This problem has become more frightening than ever before due to lack of administrative discipline and legal authority.

There is rapid urban growth caused by ethnic conflict in Kirkuk City, which is a large city in northern Iraq. This area is the study location of this research. It is characterised by political transformation, ethnic diversity and varying patterns of social interaction, all of which make decision-making difficult especially with the presence of oil in large quantities. After the Second World War, ethnic conflicts were severe due to the presence of oil (Stansgiel, 2009). This condition has made Kirkuk City a complex city with different ethnic groups fighting for resources and power because of its oil wealth.

The inconsistencies in the city's Master Plan which were caused by political changes, have led to unexpected and undesirable urban growth. This urban growth is also the result of poor and unorganised urban planning which influences the future structure of the city. As a result of these urban problems, a Master Plan was developed for the U.S. government by Pell Frischmann Consultancy. According to the US government's Iraq Transition Assistance Office, the project is an "extremely high priority" and will enable the US to "effectively empower the Kirkuk government" (Stewart, 2007).

However, this proposal failed to gain ground for the following reasons:

- The ethnic conflicts in KPC (Kirkuk Province Council);
- Failure of the planning processes to incorporate adequate local input (Knights, 2010); and
- Conflict of interest between authorised political parties.

Most of the objections centred on improper settlements built around the city which were intended to facilitate the permanent resettlement of Internal Displaced Persons (IDP) through infrastructure provision. This rejected Master Plan proposal instead focused on urban renewal in many of the peripheral areas where Kurdish IDPs had already been settled (Knights, 2010).

There were two stages of ethnic conflicts that led to rapid population growth in Kirkuk City. The first was the policy of Arabisation (Stansgiel, 2009) which came as a result of the fight over the resources in the area. In order to control the resources, more Arabs were allowed to occupy the city, thereby leading to the expulsion of indigenes. A large

number of Arabs were permitted to come to settle there; they were given jobs, security (Letayf, 2011) and open green land which they converted to residential areas thereby leading to the destruction of green lands (Kamona, 2009). The unbalanced Arab population increase which was the result of this Arabisation policy, led to the revival of the city's original Master Plan which was designed by Greek company, Doxyaids, in 1975 for the Ministry of Municipalities of Iraq and facilitated by political involvement (Frischmann, 2007).

Kurdisation policy was the second stage that promoted population increase in Kirkuk City. As a reaction to Arabisation after the political transition in 2003, thousands of Kurds returned to Kirkuk City. This resulted in increased informal settlements in the city which in turn negatively affected the Master Plan. Due to this increase in population, the available infrastructure and services were unable to meet the needs of these new informal settlements. This disorganised spatial development led to the urgent need to combine cooperative action to deal with social problems by providing technical and social infrastructure (Dwyer, 1975). Conflict of interest also played a role in the failure of the city's Master Plan which occurred due to non-stop escalation of this problem. This type of problem also continued to grow because, as mentioned earlier, these informal settlements had their own rules and regulations peculiar only to them (Dwyer, 1975).

It is crucial to realise that the future of Iraq hinges on finding a solution to the problem of Kirkuk City's status with a formula that is mutually acceptable to all ethnic parties. It must be accepted that any attempt by the Kurds to impose a solution by forcibly annexing Kirkuk for the Kurdistan region risks plunging northern Iraq into an indefinite period of violence and ethnic upheaval. Equally crucial is the fact that any effort to force an unacceptable solution on the Kurds will inevitably produce a similar undesirable outcome (Romano & Romano, 2007; Stansfield, 2009).

Although a number of studies have been carried out, there is a knowledge gap that exists regarding spatial ethnical development as most of these studies have been descriptive rather than exploratory. To fill this gap, the current study investigates the phenomenon of rapid urban growth based on ethnic conflict and methods of controlling and modelling the spatial phenomenon so as to better understand development issues based on ethnic conflict. This will in turn provide understanding and highlight how theoretical and conceptual understanding can make sense out of what appears to be a confusing issue. Also, the study intends to examine the factors that have the strongest impact on abnormal urban growth, investigate urban growth mechanism, urban processes and their effects while attempting to visualise the appearance of the city when it is well-organised and planned.

1.3 Research Questions

The following research questions are formulated:

1. What are the common factors that influence urban sprawl in Kirkuk City?
2. Does the distribution of socio-ethnic groups influence the trend of Kirkuk City's development and the reshaping of its appearance?
3. What are the future patterns of Kirkuk City's growth that are influenced by socio-political factors?

1.4 Research Objectives

General objective is aim at examining Kirkuk city's urban growth and the factors that influence its development. It investigates the impact of socio-political conflict represented by ethnic conflict on urban growth and settlement development of Kirkuk City. A model is developed to simulate the residential areas for each ethnic group with an approach that will bring about better understanding of the dynamics of urban growth based on ethnicity. To achieve the stated aims, there are three main research objectives:

1. To identify the factors that influence urban growth in Kirkuk city.
2. To compare and analyse the previous and current Master Plans of Kirkuk City that were affected by socio-political factors; and
3. To develop a spatial model and simulate the future expansion of Kirkuk City on the basis of socio-political factors and ethno-political conflicts.

1.5 Significance of the Study

Despite the fact that a number of studies have been conducted, most of them were descriptive and lacking in explanatory features. Thus, this study brings to light how future spatial urban growth based on ethnic conflict can be simulated and projected in line with the social and ethno-political factors that influence this development. So as to enable policy, decision makers and city managers are able to monitor a city's performance over time while planning and managing urban growth based on the patterns of ethnic growth.

From a theoretical perspective, it is hoped that the findings of this study will make a meaningful contribution to the growing body of literature regarding the studied phenomenon. This research also serves as a contribution to the existing body of academic and professional knowledge in the field of social urban planning by highlighting the pattern of urban expansion on the basis of ethnic group distribution and the political interface of the Master Plan. This study also evaluates, assesses and investigates the non-predictable factors such as future political decisions and changes with the uncertainty of social instability that may impact growth of the city and reshape the Master Plan. It is also hoped that this study will facilitate the reproduction of the monitored development in order to help decision makers and city planners and managers to understand the suitable methods to be used for future master plans, thus

avoiding the mistakes and shortcomings of past Master Plans. In addition, the study reveals the unpleasant degrading effects of patterns of abnormal growth within the city of Kirkuk. A multi-ethnic city is a far more complex project that requires its managers to have and effectively use available information to manage the city and guide it along the best path to achieve its development aims.

This study will be of tremendous help to policy and decision makers in the area of urban planning and management as the work develops a model that will help solve the problems related to social urban growth. Finally, it serves as reference material for general purpose research and student researchers.

1.6 Scope of the Research

This study focused on modelling urban growth based on ethnicity and in line with the changes that occurred in Kirkuk City's Master Plan through the use of combined CA-Markov approach and alongside Multi-Criteria Evaluation (MCE). The principles of transition rules were derived by using a detailed qualitative survey. In order to achieve this, decision makers from various fields were asked to participate in the study by providing their most preferred methods of weighting in creating suitability maps; weights obtained from this survey were used in the derivation of transition rules.

A simulation of Kirkuk City's ethnicities in 1984 and 2000 was carried out to obtain images for 2016 for each ethnic group. The same procedure was followed using images from 2000 and 2013 to predict ethnic distribution for 2026. This model was used to visualise the shape of Kirkuk City and to project the future urban development trend of the growth change according to ethnic distribution until 2026. For accuracy, Kappa Methods were used to validate the model.

1.7 Outline of the Thesis

This thesis has five chapters consisting of the following elements:

Chapter One contains an introduction of the research, background of the study, problem statement, research objectives, research questions, scope of the study, significance of the study and an outline of the entire thesis.

Chapter Two presents a review of theoretical and methodological literature related and relevant to this study. An overview of land-use planning, ethnicity and its effects on the economy and institutions, theories of modelling, an explanation of the concept of Cellular Automata and its use in urban modelling are all contained in the literature review. In addition, the use of Multi-Criteria Evaluation (MCE), Geographical Information System (GIS) and Remote Sensing (RS) in urban planning are also discussed in this chapter. Finally, methods of combining CA models with MCE are presented in the conclusion of the chapter.

Chapter Three contains preparation of data for modelling the study area. In this chapter, short descriptions of natural and socio-economic and socio-political factors that influence urban development in Kirkuk City are presented.

Chapter Four shows the ethnic factors responsible for urban growth and how they can be represented in Cellular Automata. It also presents the classification of transition rules through maps of suitability. Modelling based on user interface and design of database is also discussed here. Finally, definitions of MCET and CA-Markov models of urban expansion alongside its components are given in this chapter.

Chapter Five, the final chapter of this work, contains the conclusion, contributions of the study, suggestions for further related research and some of the limitations of this study.

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