UNIVERSITI PUTRA MALAYSIA

GIS- BASED ENVIRONMENTAL MODELING FOR INTEGRATION OF URBAN ACCESSIBILITY AND AIR QUALITY

MEHRDAD HADIPOUR DAHSHAL

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GIS- BASED ENVIRONMENTAL MODELING FOR INTEGRATION OF URBAN ACCESSIBILITY AND AIR QUALITY

By

MEHRDAD HADIPOUR DAHSHAL

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

February 2008

This Thesis is dedicated to

My wife Sharareh

My Son Parsa

and my parents

Who are my reasons for

Study, Work and Life

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

GIS- BASED ENVIRONMENTAL MODELING FOR INTEGRATION OF URBAN ACCESSIBILITY AND AIR QUALITY

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Chair: Associate Professor Ahmad Rodzi Mahmud, PhD

Institute: Institute of Advanced Technology

Good establishment of urban transportation network in proportion to residential zones is an important element in urban planning. Increasing urban network has both positive (accessibility) and negative (air pollution) impacts. Accessibility and air quality are chosen as key elements with respect to their critical roles in quality of life and environmental impacts. A spatial and mathematical model is useful to find the effective functions and activities on accessibility and air quality. Also, it has capability to assign quantitative values to these functions. The overall objective of this study is to develop a decision support tool to plan appropriate locations for residential landuses and urban transportation network development through the use of spatial technologies to address two issues - accessibility and air quality.

Methodology of this study helps to select suitable sites for development of urban transportation network and residential zones. Petaling Jaya, a

developing city in Selangor, Malaysia has been chosen as a case study. This method can explain the linkage between accessibility and air quality. It covers the optimum accessibility from residential to commercial and administrative area along reducing air quality. There are two main focuses in this method: definition of the optimum distance between residential zones and roads based on mathematical model, and definition of the optimum location of residential zones in proportion to urban transportation network. In this method, calibration of a complex mathematical spatial decision support model for air pollution monitoring and quantitative interpretation of urban accessibility explores and arranges important criteria such as traffic volume, wind speed, and travel time which could be interpreted to predict suitable landuses and urban networks location in quantitative framework.

The main finding of this research is a mathematical model, with about 90% accuracy, can be applied for the study area to find optimum distance from roads to avoid air pollution. Exploring potential locations for residential land use development as series of suitability maps to show current suitable and potential locations for future development is another finding of this research. Series of maps and quantitative parameters analyzed to find some area with good accessibility and air quality. The results show 66 % of study area has good accessibility and 20% of study area has potential for air pollution. The potential polluted areas are mostly located in residential landuse. Combination of accessible and non polluted areas with vacant lands and current residence areas show that 60% of current residential area are allocated in good accessible and air quality locations and with current

transport network, 8% of study area has potential to develop for future. Also, there is a need to re-design of transportation networks and landuses for future development of residential zones. The spatial scenario planning framework developed in this research is an example of an effective integrated decision-making framework.

This research has successfully managed to develop a scientifically based approach to convert conceptual configuration of non polluted and accessible areas into strategic locations using geospatial technology. Modeling for emitted air pollution by transportation, interpretation of transportation accessibility and analyzing the successful and non-successful current and future development has provided an efficient spatial approach for urban planning. It is hoped that this mathematical and spatial based approach can be employed in transportation planning and residential landuse suitability assessment at both the local and structure plan levels.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagi memenuhi keperluan untuk ijazah Kedoktoran Falsafah

PEMODELAN ALAM SEKITAR BERASAKAN GIS UNTUK INTRGRASI KEBOLEHLALUAN DAN KUALITI UDARA BANDAR

Oleh

MEHRDAD HADIPOUR DAHSHAL

Februri 2008

Pengerusi: Professor Madya Ahmad Rodzi Mahmud, PhD

Institute: Institute Teknologi Maju

Penubuhan rangkaian pengangkutan bandar yang baik dan sekadar dengan zon-zon kediaman adalah unsur penting dalam perancangan bandar. Rangkaian bandar yang semakin meningkat mempunyai kedua-dua impak positif (kebolehlaluan) dan negatif (pencemaran udara). Kebolehlaluan dan kualiti udara telah dipilih sebagai unsur-unsur utama dari segi peranan-peranannya yang kritikal dalam kualiti kehidupan dan impak alam sekitar. Suatu model matematik dan spatial adalah berguna untuk memperolehi fungsi-fungsi dan aktiviti-aktiviti yang berkesan pada kebolehlaluan dan kualiti udara. Model ini pula mempunyai kebolehan menentukan nilai-nilai kuantitatif bagi fungsi-fungsi tersebut. Objektif menyeluruh kajian ini ialah membangunkan suatu peralatan menyokong pembuatan keputusan untuk merancang lokasi-lokasi sesuai bagi tujuan gunatanah kediaman dan pembangunan rangkaian pengangkutan bandar.melalui penggunaan teknologi *spatial* untuk menyelesaikan dua isu – kebolehlaluan dan kualiti udara.

Metodologi yang digunakan dalam kajian ini dapat memilih lokasi-lokasi yang sesuai untuk pembangunan rangkaian pengangkutan bandar dan zon-zon kediaman. Petaling Jaya, satu bandar raya yang sedang membangun di negeri Selangor, Malaysia, telah dipilih sebagai kes kajian. Keadah ini dapat menerangkan perhubungan antara kebolehlaluan dan kualiti udara. Ia meliputi kebolehlaluan optima daripada tempat kediaman ke kawasan komersial dan pentadbiran melalui zon-zon kualiti udara yang semakin buruk.

Terdapat dua fokus utama dalam metodologi ini: definasi jarak optima antara zon-zon kediaman dan jalan raya berasaskan model matematik; dan definasi lokasi optima bagi zon-zon kediaman selaras dengan rangkaian pengangkutan bandar. Dalam metodologi ini, kalibrasi model penyokong pembuatan keputusan yang merupakan matematik, spatial dan komplex ini untuk memantau pencemaran udara dan penafsiran kebolehlaluan bandar berkuantitatif , dapat menjelajah dan menyusun kriteria-kriteria penting seperti keberatan trafik, kelajuan angin, dan masa perjalanan yang boleh ditafsirkan untuk meramalkan kesesuaian gunatanah dan lokasi rangkaian bandar dalam rekabentuk berkuantitatif.

Penghasilan utama penyelidikan ini ialah satu model matematik, dengan kejituan kira-kira 90 %, yang boleh digunakan bagi kawasan kajian untuk mendapati jarak optima dari jalan–jalan mencegah pencemaran udara. Satu lagi penghasilan penyelidikan ini ialah tinjauan lokasi-lokasi berpotensi untuk pembangunan gunatanah kediaman masa sekarang dan masa depan melalui siri peta-peta kesesuaian. Beberapa siri peta dan parameter kuantitatif dapat dianalisakan untuk menentukan kawasan–kawasan yang

mempunyai kebolehlaluan dan kualiti udara yang baik. Hasil penyelidikan menunjukkan bahawa 66% daripada kawasan kajian mempunyai kebolehlaluan yang baik dan 20% mempunyai potensi pencemaran udara yang kebanyakannya didapati pada kawasan kediaman. Kombinasi kawasan-kawasan kebolehlaluan dan kawasan-kawasan tanpa pencemaran dengan tanah kosong dan kawasan kediaman menunjukkan bahawa 60 % daripada kawasan kediaman sekarang telah diadakan dalam lokasi-lokasi yang baik dari segi kebolehlaluan dan kualiti udara dan juga mempunyai rangkaiaan pengangkutan tersediaada. Terdapat pula 8 % kawasan kajian mempunyai potensi untuk pembangunan masa depan. Tambahan pula terdapat juga keperluan untuk merekabentuk semula rangkaian pengangkutan dan gunatanah bagi pembangunan zon kediaman masa depan.

Rekabentuk perancangan scenario spatial yang dibangunkan dalam penyelidikan ini merupakan satu contoh rekabentuk pembuatan keputusan bersepadu yang berkesan. Penyelidikan ini telah berjaya membangunkan satu keadah berasaskan sains untuk menukar konfigurasi konsep bagi kawasan kebolehlaluan dan kawasan tanpa pencermaran kepada lokasi-lokasi strategik dengan penggunaan teknologi geospatial. Pemodelan pencemaran udara dari pengangkutan, penafsiran kebolehlaluan pengangkutan dan analisa pembangunan semasa dan masa depan yang telah berjaya dan juga tidak berjaya telah menghasilkan satu keadah spatial yang berkesan untuk perancangan bandar. Diharapkan bahawa keadah matematik dan spatial ini dapat digunakan dalam perancangan

pengangkutan dan penilaian kesesuaian gunatanah kediaman pada tahap tempatan dan juga tahap pelan struktur.

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I certify that an Examination Committee has met on **12th February 2008** to conduct the final examination of **Mehrdad Hadipour Dahshal** on his **Doctor of Philosophy** thesis entitled "**GIS- Based Environmental Modeling for Integration of Urban Accessibility and Air Quality**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy degree.

Members of the Examination Committee were as follows:

Thamer Ahmed Mohammed, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Helmi Zulhaidi Mohd Shatri, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Hussain Hamid, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Ofyar Zainuddin Tamin, PhD
Professor Ir.
Department of civil engineering
Bandung Institute of Technology
(External Examiner)

HASANAH MOHD.GHAZALI, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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:

Ahmad Rodzi Mahmud, PhD
Associate Professor
Institute of Advanced Technology
Universiti Putra Malaysia
(Chairman)

Shattri Mansor, PhD
Professor
Institute of Advanced Technology
Universiti Putra Malaysia
(Member)

Abdul Azeez Kadar Hamsa, PhD
Assistant Professor
Faculty of Architecture and Environmental Design
International Islamic University Malaysia
(Member)

_____

AINI IDERIS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MEHRDAD HADI POUR DAHSHAL

Date:

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LIST OF ABBREVIATION

- **ANN:** Artificial Neural Networks
- **API:** Air Pollution Index
- **APS:** Air Pollution section of Department of Environment
- **AQM:** Air Quality Management Toolbox
- **CO** : Carbon Monoxide
- **DEQ**: Department of Environmental Quality, USA
- **DOE:** Department of Environment, Ministry of Natural Resource and Environment of Malaysia
- **DTIM2:** Direct Travel Impact Model
- **EPA:** Environmental protection Agency ,USA
- **FHWA:** Federal Highway Administration of USA
- **FLT:** Fuzzy Logic Theory
- **GIS:** Geographic Information System
- **HIGHWAY:** Highway air pollution model
- **IPCC**: Intergovernmental Panel on Climate Change
- **ISHS:** International Society for Horticultural Science, Malaysia
- **JAG:** Journal of Applied Gerontology
- **JICA:** Japan International Cooperation Agency
- **JIRSEA:** Journal of Institutional Research South East Asia
- **JPBD:** Jabatan Perancang Bandar dan Desa (Federal Department of town and country planning, Malaysia)
- **MOT:** Ministry of Transportation Malaysia
- **MPPJ:** Majlis Perbandaran Petaling Jaya (Petalig Jaya Municipal Council)

- **MTS:** Multimodal Travel System
- **MVEI7G:** Motor Vehicle Emission Inventory Model
- **RS:** Remote Sensing
- **SEPA:** Scottish Environmental Protection Agency, UK
- **TEMMS:** Traffic Emission Modelling and Mapping Suite
- **TRB:** Transportation Research Board
- **UKM:** University Kebangsaan Malaysia
- **UNEP:** United Nations Environment Program
- **UPM:** University Putra Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background

Since the urban transportation is considered as a major criterion for human settlements, the establishment of urban landuses near the urban transportation network is the demonstration of it. In past years, early cities were small and walking was the major travel mode (Banister, 2002). Also, most of the urban transportation was done by simple vehicles through simple networks, and was affected by less population pressure and the minimum environmental problems. As the population increased, along the wide urbanization and increasing population pressure and environmental problems, the issue of urban transportation have become a major concern to professional planning. Urban development also caused more transportation movement and therefore increases air pollution and high consumption of energy or fuel to access to main urban facilities.

The development of science and technology, congestion in the city became major problem, particularly in the field of spatial planning. Historically, the formation of cities followed transportation systems along the technical and economical development. The arrival of new technologies such as Geographic Information System (GIS), Remote Sensing (RS) and Global

Positioning System (GPS) gave a digital tool for urban mapping and planning. Hence there is a need to bring back the ‘small city’ concept again, which is known as “smart growth” (Miller and Hoel, 2002, and Cervero, 2004), where emphasis to the integration of transportation accessibility and urban landuse. To accomplish the activities in big cities, importance of environmental problems should be considered in designing urban transportation systems.

Since the transportation normally includes about 20-30% of an urban land to connect the rest (Pleng and Devel, 2005), it is considered as an important element in urban land-use planning. Urban transportation planning is required when a large number of residents and people depend on city services and employments. Urban transportation network isn’t developed in all over the city with same level; an area next to the main road does not get considerable benefits from its existence (closeness to main road). The location of destinations (usually official and commercial land-uses) will influence the urban transportation as it will improve regional accessibility and air quality, and thus lead to higher land values in the surrounding area (Cervero, 1994).

As transportation is one of the most important infrastructures of a city, its location-allocation is important for urban planning. The balance between transportation and landuse components of urban planning is very important,