URBAN LAND USE AND ECONOMIC GROWTH MODELLING

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ABSTRACT

Urbanisation and economic growth are strongly related. In urban growth processes, urbanisation is strongly influenced by economic growth and also the economy inequality within the area. Urban growth triggers the dynamics in the urban system which consists of a complex subsystem including multiple actors with different patterns of behaviour at various scales. Therefore, in order to understand this complex system, multi-agent systems which make explicit the decision making process of the various actors may be useful to help and identify the complexity of these processes. Such a model will be a foundation to facilitate town planners and decision makers to identify factors that will contribute to understand the relationship between economic growth and dynamic land use patterns in their region. To this end, this paper will discuss progress in integrating land use modelling techniques with a multi-agent system which is linked with GIS technology for understanding and simulating economic growth in the Klang Valley region in Malaysia.

Keywords: Regional Economic Growth, Multi-Agent, Geographical Information System, Urban Sprawl, Firm Demography.

INTRODUCTION

Urban planning and transportation modelling have in common a long history of modelling urban dynamics. These disciplines have however used to some extent different modelling approaches. In urban planning, over the last decades, especially cellular automata (CA) models have been developed and applied. These models divide the area of interest into grids cells. Each cell has a certain land use. Cells are classified according to their suitability for particular land uses. Urban dynamics are simulated by developing or assuming transition rules which represent the probability that a particular land use will change into another type of land use. Approaches differ in terms of differences in these transition rules and the demarcations of the influencing cells (Batty *et al.*, 1997). Semboloni (1997) included the eight surrounding cells. White and Engelen (1993) defined the neighborhood of a cell to be cells within a radius of 6 cells, so that according to this definition the neighborhood contains 113 cells. Couclelis (1985) defined the size of the neighborhood differently for each land use, while Vancher *et al.* (2005) also argued that the neighborhood should be based on the relevant interactions. In the beginning, may transition rules were stochastic. Batty and Xie (1994) suggested a non-deterministic model. White and Engelen (1993) used a hierarchy of land-use states such that a cell may only be transformed from a lower to a higher state. In later studies (White and Engelen, 1997) this restriction was relaxed. Wu and Webster (1998) who took into account that the transition of non-urban space into cities depends on global as well as local processes. A final example is Yeh and Li (2001) who suggested the new concept of “Grey-Cell”. The state of a cell in a “Grey-cell” method is expressed by a continuous value for development or conversion. The value indicates the cumulative degree of development for a candidate cell before it is completely selected for development or conversion.

In contrast, integrated land use transportation models have been dominant in transportation research. The core of this modelling approach is a transportation demand model that is applied to a given spatial configuration of land uses. It results in a distribution of traffic, travel times and perhaps congestion. These travel times are then used as input to measure accessibility. Land use change is then modelled as a function of changing accessibility, and iteratively urban dynamics are then simulated.

Although both these approaches have proven their usefulness, their potential weaknesses have also been debated. It seems that these modelling approaches have reached their point of satiation and that new concepts and approaches may be needed to revitalise this area of research. One of the major potential weaknesses of these modelling approaches is their weak behavioural basis. In the context of cellular automata models, cells are not decision-makers and transition rules are not defined in terms of behavioural mechanisms but are largely treated as data fitting exercises in an attempt to find the set of rules that are consistent with observed empirical changes in land use patterns. While this may be sufficient to describe urban dynamics, it is questionable whether these models can be used for prediction if the set of factors and conditions acting on observed land use change patterns change over time. Our contention is that behavioural principles are less sensitive to external circumstances than revealed changes may suggest and change only gradually over time. It this argument is accepted, behaviourally stronger models should be more robust.

It may be argued that the integrated land use transportation models include a richer set of behavioural principles. However, assuming that location decisions of firms are mainly based on the concept of accessibility does little justice to the results of empirical studies in regional science and economic geography, which suggest that the location decisions of firms are part of their overall business model and influenced by a larger set of considerations, some of which are related to preferences, others to constraints.

To avoid these problems, multi-agent models have been advocated as an alternative to these dominant modelling approaches. An agent in this context represents a decision maker that makes location decisions, party independently, partly in reaction to the location decisions of other agents. The philosophy behind this modelling approach is then that urban growth patterns emerge as the cumulative effect of these individual decisions. In that sense, multi-agent models are assumed to better allow investigating urban land use as a complex system. Models are built in order to understand urban dynamics since these tools, in mimicking part of the urban system, can provide valuable information on the system's behaviour to planners.

Despite the potential of agent-based models to simulate urban dynamics, very little progress has been made, especially if we ignore those models claiming to be multi-agent models but which in reality stay very close to conventional integrated land-use transportation models. This paper therefore, contributing to the debate, explores the potential of multi-agent models in simulating urban dynamics. This study aims at developing a multi-agent model to simulate dynamic land use patterns and growth in regional economic development areas. The paper reports progress, but also identifies some issues that need an original solution to develop such a model as an alternative to cellular automata and integrated land use transportation models. In that sense, we hope to contribute to the discussion.

Problem Statement

The main aim of this research project is to identify the role and relevance of MAS for planning support in urban economic growth development areas. In achieving sustainable development in Malaysia, urban planning activities have changed from simple objectives to a more complex exercise improving comfort living conditions. This is due to the government initiative to introduce development programs to accelerate economic growth and elevate income levels to improving the quality of life of people. Furthermore, with the new trends of economic regional development in Malaysia, it may be relevant to develop a model which simulates growth within the region. Ideally, this model will facilitate town planners and decision makers to better understand the impact of their decisions in terms of the relationship between economic growth and dynamic land use patterns in the region. This study therefore aims at integrating land use modelling techniques and MAS, using Geographic Information Systems (GIS) technology for data handling and visualisation. Spatial analysis and complexity modelling will be applied in a detailed case study to simulate land use change in the economic region of Klang Valley in Malaysia.

URBAN LAND USE AND ECONOMIC GROWTH MODEL

Understanding Urban Land Use

Understanding urban and regional growth is important in order to model it since it involves several actors with different patterns of behaviour (Cheng, 2003). Urban growth can be defined as the process of growth and decline of urban areas. These urbanization processes tend to be strongly linked to economic development processes. The pattern of concentration of economic activity and its evolution has been found to be an important determinant of the structure of cities, the organization of economic activity, and national economic growth. Yet, urban growth affects the efficiency of production and economic growth, and the way agents interact and live in cities. Urban growth is related to land use in cities. In order to understand these land use pattern, models have been build to make these relationships explicit.

Early urban models were formulated in the 1950s. However the first operational model of urban land use is widely considered to be developed by Lowry (1964) and is known as "Model of Metropolis". This model was the first generation of models that is based on theories of spatial interaction. The spatial interaction models framework was continued to be developed through the early 1960s to the mid 1980s when they became mainly replaced by models grounded on random utility theory and an econometrics framework (Iacono *et al.,* 2008). This shift also meant a changing focus from aggregate, spatial analysis to disaggregate non-spatial analysis. Starting in the early 1990s, researchers have dedicated their effort to develop comprehensive urban micro-simulation models, and cell based models which reflect the dynamics of change in urban environments. These modern era models backed with advances in computing technology and efficiency, allowed researchers to undertake a more complex series of model development, for instance, through the integration of new technology such as GIS to create a new generation of models. Figure 1 shows the chronological development of land use and transportation models.

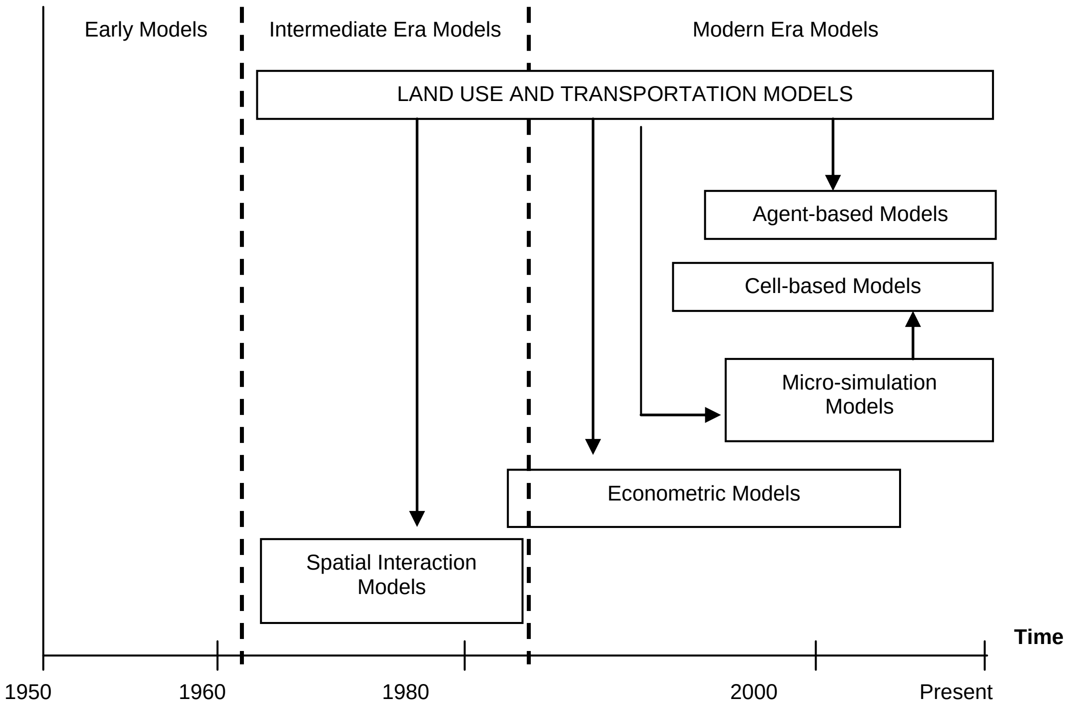

Figure 1 - Chronological Development of Urban Land Use models

(Source: Modified from Iacono *et al.*, 2008)

How to Incorporate Economic Growth?

Economic growth can be described as changes or increments in the level of production of goods and services in the economy of a country over a period of time. To the extent that economic growth is reflected in urban growth, it is often manifested in changes in land use patterns. In general, some amount of growth can be captured in the existing building stock and associated land use patterns, but increasing growth tends to induce land use change.

The problem and difficulty is to how to incorporate economic growth in agent-based models. Although there are differences between models, integrated land use transportation and cellular automata models typically first estimate a model of economic growth such as a spatial input-output model, sometimes linked to assumptions or a model of external urban growth. These models then predict the impact of change in the economy in one sector or region on other sectors in other regions. This change is assumed to reflect a changing demand for land use. Finally, this additional demand is allocated across locations as a function of accessibility and suitability. This mechanism of including economic growth into these models is hierarchical and aggregate and far removed from the premise of agent-based modelling of behavioural realism. The question then is what alternative approach may be employed?

Based on the notion that location decisions are part of their business model and its inherent dynamics, it has been argued that perhaps the demography of firms or Firm demography may be valuable approach. This concept focuses on the demographic transformation of firms in the region and its correlation with land use changes. Firm demography can be defined in terms of the lifecycles of a firm which are similar to human lifecycles that consist of birth, death, and changes in the number of employees of the firm. Seminal work on this concept goes back to David Birch's study on 'job generating processes' in the USA (Birch, 1979). He advocates that the economic development of a region consists of birth, death, and migration of firms which can be considered as the basic components of development (Van Dijk and Pellenbarg, 2000b). In recent years, firm demography has caught some attention in organisational sociology (Carroll and Hannan, 2000), economics and economic geography (Van Wissen, 2002), industrial organization (Geroski, 1995; Audretsch *et al.,* 1997); (Caves, 1998), regional science (Van Dijk and Pellenbarg, 2000a) and transportation (Moeckel, 2005). We decided to use the concept of firm demography in this study, but the concept probably needs some elaboration. Existing models have basically used the concept only to have an accounting system that predicts the future number of firms in particular segments and their size as a function of births, deaths and relocations. To the extent these drivers of change are predicted, often again the well-known aggregate models are used. This remains far from a richer theoretical framework. Hence, the challenge is how to model decisions about growth/decline, start and closure and relocations as a function of external factors. The special links between firm dynamics and urban dynamics will give firm demography the connotation of an intermediate concept linked with economic growth.

Malaysia's Urban Planning System and Economic Growth

Urban planning activities in Malaysia has evolved from the simple objective of improving living conditions to a more complex exercise of facilitating the achievement of sustainable development in the country. This is due to the intensity of development activities that require determining issues such as those relating to location, size and patterns of land utilization.

Table 1 shows Malaysia's Vision and National Planning System from the year 1947 until now. The vision is the revolutionize government development. The national planning development plan is a written policy document that includes supportive statistical data to define Malaysia's terms of development and that sets the agenda for socio economic change (Bruton, 2007). This vision and development plan emphasise Malaysia planning strategies for generating sustained economic growth to ensure that the benefits of growth can be shared among all Malaysians in an equitable manner.

Table 1 - Malaysia's Vision and National Level Planning System

Plan Content	1947-1957	1958-1970	1971-1990	1991-2000	2001-2010
Vision	British Colonial	Old Economic Policy	1. New Economic Policy 2. Outline Perspectives Plan 1	1. New Economic Policy 2. Outline Perspectives Plan 2	National Vision Policy
Planning at National Level	Plans for Economic Development	Plans for Economic Development	Development Plans Plans 1-5	Development Plans Plans 6-7	Developments Plans Malaysia Plans 8-9 National Physical Plan

Source: Modified from (Bruton, 2007)

The Malaysian economy has generated an average Gross Domestic Product (GDP) of 6.2 per cent per annum from 1991 to 2005 and was expected to grow at a healthy rate of 8.5 per cent a year between 2006 until 2010 (Parliament of Malaysia, 2006). With the previous and current economic situation in the country, it explains the relation to firm performance in a later part of the paper. Although this research is not directly related to an economic study, the economic indicators and government policy need to be taken into consideration because firm demography is influenced by these.

GIS AND MAS INTEGRATION

Currently, the employment of Information and Communication Technology (ICT) is seen as an evolving approach to improve urban governance. GIS is a tool for decision making and for providing planning information. GIS tools have the ability to build complex and interesting spatial models that represent patterns of urban development, although that may take some effort as their script languages are not necessary the best in this regard. At the very least, however, geographic information systems are highly appropriate for spatial data handling and visualization of model output (Davis, 2001). Geo-reference is the most important feature of GIS and this functionality is very useful for spatial modelling. Applications based on spatial reference will create better geo-simulation (Benenson and Torrens, 2004). Meanwhile, multi-agent systems have the capability to represent the processes underlying a particular phenomenon or activities.

According to Cheng (2003), multi-agent systems can be defined as a collection of interacting autonomous agents, each with their own capacities and goals but related to a common environment that can involve communication, such as passing of information from one agent and environment to another. He also claims that agent-based simulation is ideally suited to explore the implications of nonlinearity in system behaviour and also lends itself to models that are readily scalable in scope and level. MAS is a loosely coupled network of problems solvers that interact to solve problems that are beyond the individual capabilities or knowledge of each problem solver (Durfee and Lesser, 1989). In urban systems, Multi Agents may also be a useful tool for representing mobile entities in urban environments such as people, households and vehicles. They have been used in urban contexts to simulate pedestrian movement in urban environments (Kerridge *et al.,* 2001) and relocate households (Benenson, 1998). It is unlikely that a model of urban evolution will need that level of detail, but in any case these examples of multi-agent systems do indicate that these systems are more appropriate to include a wide variety of behavioural principles and co-evolutionary decision strategies. Thus, the integration of GIS and MAS would allow the simulation of urban dynamic development and has potential to simulate, display, analyze and present data using a common platform.

GIS technologies are very useful for this because GIS allow agent-based modellers to relate agents to actual geographic locations. Therefore, the integration of GIS and MAS will enhance the capability of urban simulation techniques (Brown *et al.,* 2005); (Parker, 2005); (Torrens and Benenson, 2005). The integration of MAS and GIS enables exploring how heterogeneous individual decisions of agents translate it into aggregate rates of a phenomenon (Mathur, 2007).

Integration of GIS and MAS modelling in the urban dynamics domain has been studied before in several aspects. Gonçalves *et al.* (2004) for example, recommended a conceptual environment for coupling GIS and MAS simulation tools. Their MAS-GIS model was used to study the impact of a particular policy by modelling the behaviour of industrials under certain circumstances. A Shell for Simulated Agent Systems (SeSAM) was developed as a tool that provides a generic environment for modelling and experimenting in agent-based simulation

(Schüle *et al.,* 2004). SeSAM is a generic solution of GIS-MAS coupling that can be used for many applications which need real-world geographical data. Karadimas *et al.* (2006) developed a system which integrated GIS and MAS in a Decision Support System for waste management. The system provides substantial benefits to stakeholders in dealing with urban solid waste management. These and other examples show that earlier approaches in a variety of application domains demonstrate how GIS and MAS can be integrated successively to provide better solutions in modelling urban phenomena.

STUDY AREA

The development of economic regions is one of the forms of the national mission in Vision 2020 motivated by Malaysia's former Prime Minister Dr. Mahathir. The initiative of economic development areas was inspired by the successful Klang Valley region development which is known as the heartland of Malaysia's industry and commerce. With diverse development concepts, it aims to achieve the goal of accelerating economic growth and development, and improving the quality of life for the people in these regions. Five new economic development corridors throughout the country were initiated and are being developed since 2005: Iskandar Development Region (IDR), North Corridor Economic Region (NCER), East Corridor Economic Region (ECER) Sabah Development Corridor (SDC) and the most recent The Sarawak Corridor of Renewable Energy (SCORE). Thus, with these economic development regions, it is realistic to develop a model that simulates growth within these regions. Yet, after considering data availability, it was decided to focus on the Klang Valley region as the study area.

Location

Klang Valley is a region in Malaysia which is comprised of Kuala Lumpur and its fringes and neighbouring cities and towns in the state of Selangor. Klang Valley has no official boundary, yet it is currently comprised of six districts which are Kuala Lumpur, Putrajaya, Gombak, Hulu Langat, Klang and Petaling (Figure 2). The physical site of the area was encouraged by the development of commercial, industrial and residential activities which made Klang Valley grow rapidly. With a population of 5.78 million people (Department of Statistics Malaysia, 2008) and areas covering up to 2,826 km^2, Klang Valley has the most urbane transportation hierarchy in Malaysia. Rather than a road system, integrated rail transport which consists of monorail, electrified commuter, light rail transit (LRT) and Express Rail Link (ERL) are build for Klang Valley's residents and workers to commute within the region which make it the most important region in Malaysia. This region is also served by two airports: the Kuala Lumpur International Airport (KLIA) in Sepang, which is the main international airport for Malaysia, and Sultan Abdul Aziz Shah Airport in Subang, which handles general aviation and turbo-prop domestic flights (2010).

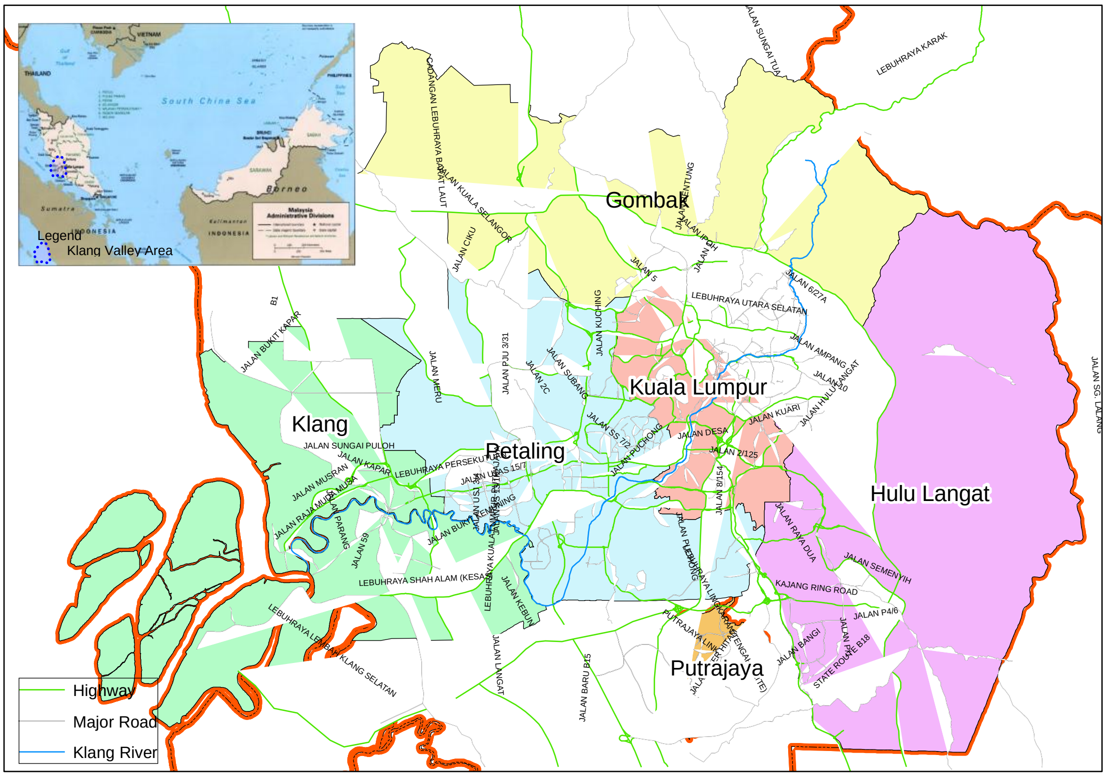

Figure 2 - Klang Valley Region

GIS DATABASE DESIGN AND DEVELOPMENT

Data Source

This study will utilize data from various sources, including GIS spatial and attribute data. The land use data of Klang Valley is obtained from Klang Valley Federal Territory (KVFT), demographic data from the Department of Statistics Malaysia and firm data which consist of companies registered in Malaysia are acquired from Company Commission of Malaysia (CCM). Other data to support the application such as transportation, administration and physical data are obtained from KVFT.

The data are collected by visiting the targeted agency. In order to get accurate and precise data, every single spatial data is required to have a standard geo-reference. Thus, the data needs to be edited and manipulated. Attribute data were collected from various sources such as compilation of scientific reports, collections from site surveys, various digital forms data in multiple formats such as database, spreadsheet tables, and internet as well as raw data. All these data were adapted to a standard format and stored in a relational database management system which has the ability to relate to other databases.

Data Classification

The structure of the GIS database for this study is focused on the needs of our project: land use development. For this study, there are several data layers in the database:

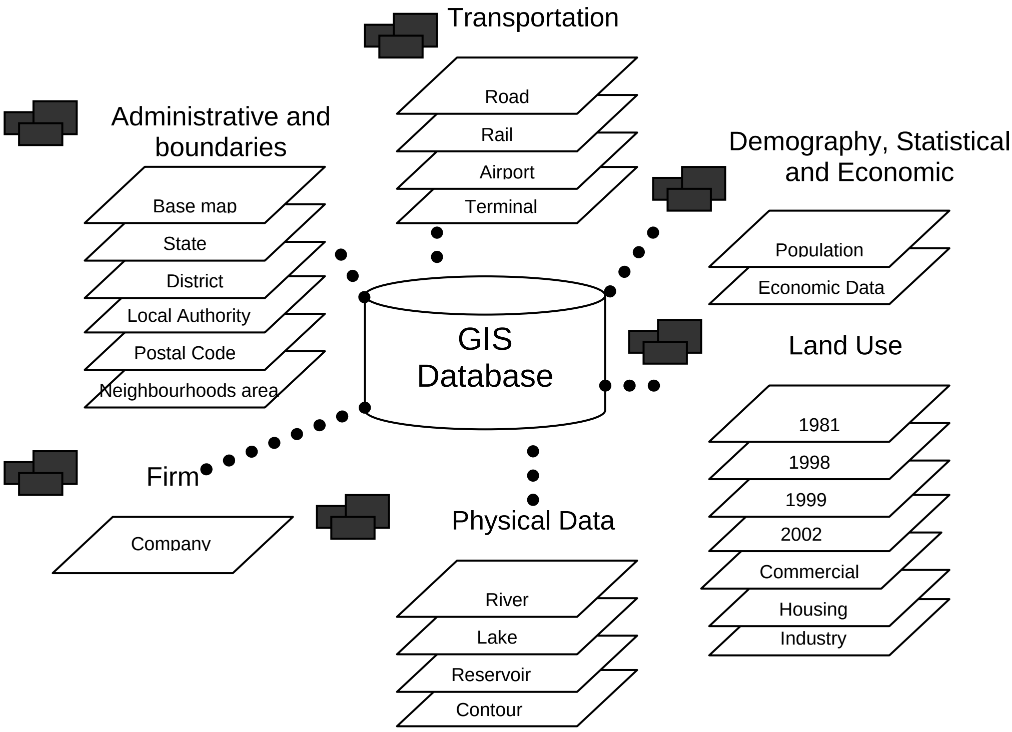

Figure 3 - GIS Database

Administrative and Boundaries

Administrative data include administrative information for the Klang Valley region. The most important data is the base-map data which contain detailed parcels of land in the study area. Other data are boundary data for states, districts, local authorities, postal areas and neighbourhood communities in the area.

Physical Data

Physical data for this database are comprised of lakes, rivers, reservoirs, drainage and contour data. This data can be used to support some part of the spatial analysis.

Land Use

In this study, land use data for the years 1981, 1998, 1999 and 2002 were obtained from the land use maps made available digitally by KVFT. The land use categories include residential, commercial and services, industrial, transportation and communication, utilities and public amenities, agriculture, forestry and institutional.

Transportation

Transportation data relate to present, proposed and dedicated road, airport, rail and main bus terminal facilities. This data is needed to calculate the accessibility of the areas for different modes of travel. Thus, transportation data such as highway may also influence the location decisions of new firms.

Demographic, Economic and Statistical data

Demographic data is available for the years 1991 and 2000, listing the population by age group, gender, race and district. The data from the Statistical Department consists of Statistical reports related to businesses, population, employment and economic indicators. Economic and statistical data are important in order to analyse and project growth.

Firm Data

Firm data has been obtained and contains information about registered companies in the study area between 1990 and 2007. In firm demography research, a basic problem is the lack of datasets of up-to-date firm data (Van Dijk and Pellenbarg, 2000c). For this study, partial data is available such as date of start-up, firm address, firm status and type of firm but no information is available about migration, closure date or employment status.

FIRM DATA ANALYSIS

The first stage of firm data analysis was conducted for the years 1990 until 1994. This preliminary analysis served as a guide to decide on the method that will be used for later periods of firm data.

Geocoding Firm Addresses

The firm data which were obtained from CCM were in spreadsheet format. In order to display firm locations in spatial environments, geocoding was used. Geocoding or address matching is the process of assigning a location, usually in the form of coordinate values, to an address by comparing the descriptive location elements in the address to those present in the reference material (ESRI, 2003). Based on the data, addresses come from common address formats of a company premise number followed by the street name, postal zone and area.

Figure 4 shows the geocoding process for this study. Firstly, road data was created as an address locator. An address locator is a compulsory indicator for geocoding which allows conversion of textual descriptions of locations into geographic features. Road data is selected because it is the most suitable matching entity and can represent the firm location. To geocode addresses, company data will be the input and road information will be the key field for matching the address.

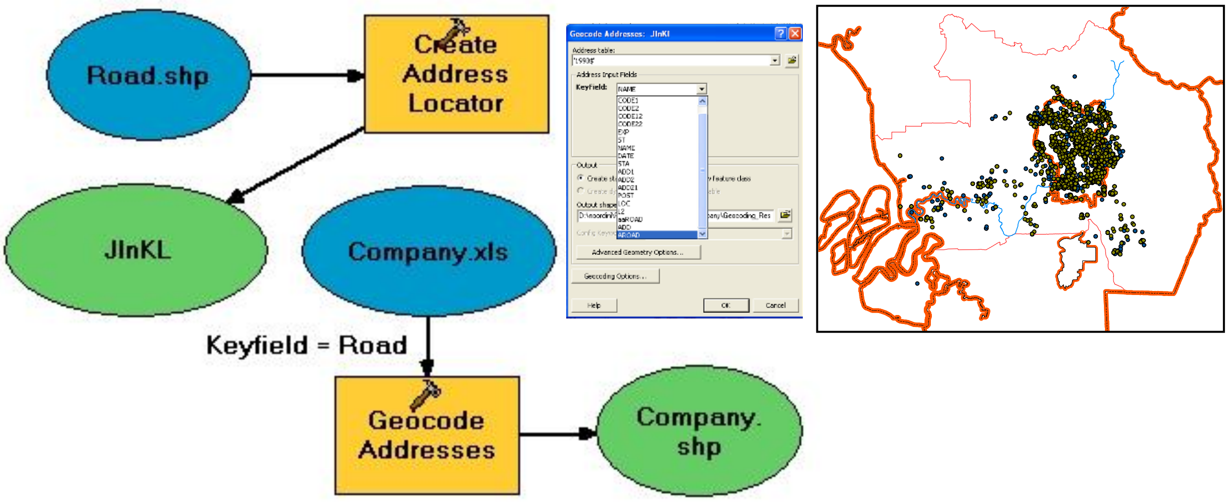

Figure 4 - Firm data locator process

Table 2 provides summaries of the results produces from the geocoding address process. As can be seen the result shows that only less than 2 per cent of the addresses could not matched because of data entry errors and missing or incomplete address information particularly the road name. Most of the geocoded address fall close to the reference data locations.

Table 2 – Summary of Geocoding process

YEAR	1990		1991		1992		1993		1994	
RESULT	Number	%	Number	%	Number	%	Number	%	Number	%
Matched	3487	98	3839	98	4154	99	5466	99	6953	98
Unmatched	62	2	86	2	49	1	70	1	142	2
Total	3549	100	3925	100	4203	100	5536	100	7095	100

Firm Dynamic and Productivity

From 1990 to 1994, Malaysia economic development was under The Sixth Malaysia Plan and Second Outline Perspective Plan. Under this development plan, Malaysia's economy performed well with the GDP growing at an average growth of 8.7 per cent per annum (Prime Minister's Department, 1996). The trade sector including firms, playing a role in generating output, income, employment and foreign exchange earnings which contributed to excellent economic performance. As shown in Figure 5, from the year 1990 until 1994, the number of births of firms increased every year in the study area. The increases of new firms are in line with Malaysia's Business Cycle Turns between 1990 and 1994 as shown in Figure 6. The business cycle is influenced by cyclical fluctuations in economic activities or processes, whereby these economic activities or processes can have widely conflicting temporal relationships to the business cycle (Department of Statistics Malaysia, 2009).

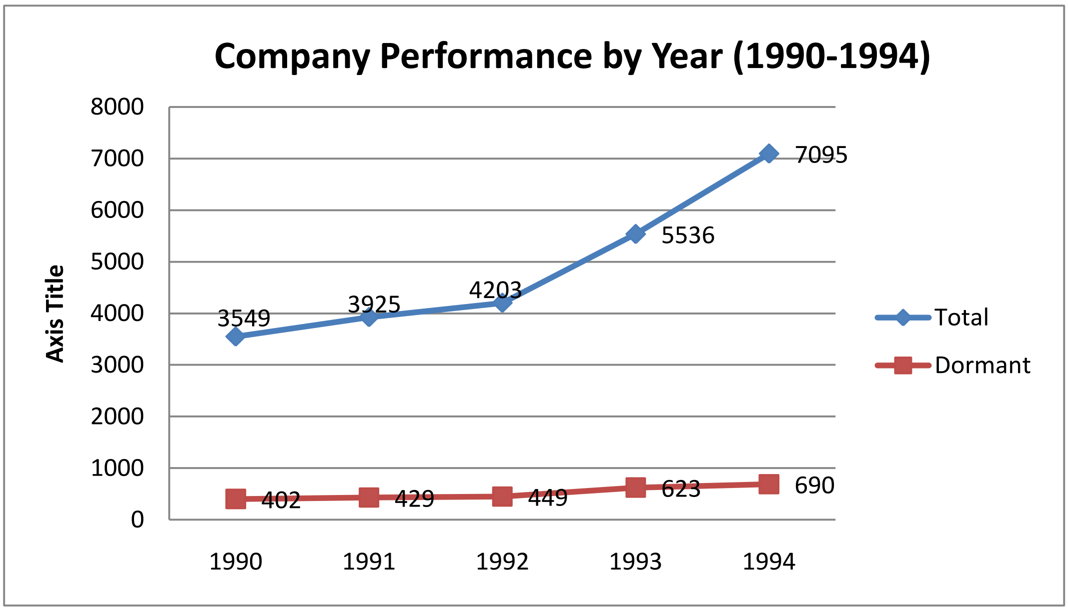

Figure 5 - Company performance for the study area (1990-1994)

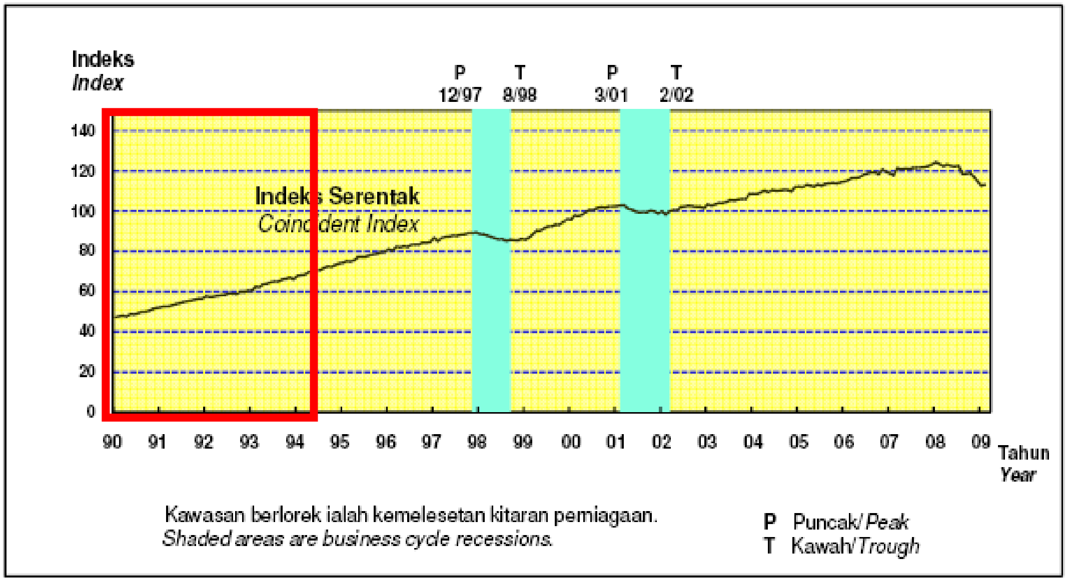

Figure 6 - The Coincident Index and Malaysia Business Cycle Turns 1990-2009.

Source : (Department of Statistics Malaysia, 2009)

The Company Commission divided the company data into 11 categories of company businesses covering all type of commerce activities (Table 3). The number of total firms over the period 1990 to 1994 in the study area are 3 549, 3 925, 4 203, 5 536 and 7 095 respectively. Taking the period into closer analysis, the entering firms are concentrated mainly in sector 10 (Financing, Insurance Real Estate, Investment and Business Services) and sector 8 (Wholesale and Retail Trade, Restaurant and Hotel). Both types of firm grew every year. The differences in firm distribution and the higher concentration of sectors 8 and 10 are most likely the result of the status of Klang Valley area as the commerce hub for the region. Other sectors have shown a rise and decline in the annual birth of new firms, but this inconsistency did not affect the increase of firms between 1990 to 1994.

Table 3 – Number of firms by categories 1990 - 1994

Code	Description / Sector	1990	1991	1992	1993	1994
1	Missing/Not adequately define	34	79	213	241	256
2	Dormant	402	429	449	623	690
3	Agriculture, Hunting, Forestry and Fishing	18	29	26	30	27
4	Mining and Quarrying	17	15	17	19	15
5	Manufacturing	283	255	195	284	311
6	Electricity, Gas and Water	8	6	8	15	17
7	Construction	267	280	304	440	500
8	Wholesale and Retail Trade, Restaurant and Hotel	925	1057	1147	1526	1878
9	Transportation and Communication	195	164	154	143	148
10	Financing, Insurance Real Estate, Investment And Business Services	1227	1423	1502	2066	2983
11	Community, Social and Personal Services	173	188	188	149	270
Total		3549	3925	4203	5536	7095

In economic development, business performance is reflecting by employment status. If economy is growing, many firm will hire employees but a few will reduce employment despite of overall economic growth (Moeckel, 2005). However, employment data for the study area is not available; therefore correlation analysis between birth of firm and employment cannot be carried out. This is one of the problems with the dataset which makes it impossible to measure labour productivity for the study area.

Using firm data analysis between 1990 to 1994, the later period firm data will apply the same method to examine firm performance. However, in addition more data needs to be acquired especially on labour productivity for more comprehensive analysis and its connection to economic growth in the region.

CONCLUSION AND DISCUSSION

This paper presented progress made in the development of a multi-agent model of urban dynamics, taking economic growth into account. The model will be developed using data of the Klang Valley and Malaysia as the larger context. The paper shows that the project is still in its infancy. In general, the success of multi-agent model will among other factors depend on data availability and richness of behavioural concepts. In the early stage of development, we therefore had to explore these issues and make strategic decisions. This paper documents this process by discussing some general literature, database development and initial analysis of the available data.

The existing literature suggest that multi-agent modelling may be an interesting alternative to more commonly used cellular automata models and integrated land use transportation models in the sense that in principle they allow for richer behavioural principles and the treatment of interdependent location strategies of multiple actors and stakeholders.

We have also articulated that the use of GIS tools will assist in data handling and visualization, while the trend of developing planning support systems based on GIS technology can also be supported. The very integration of GIS and MAS will have great impact on the process.

A main problem of developing this system, the modelling of economic development as a bottom-up development process has been emphasised. It is not immediately clear how this problem may be solved in a non-traditional way, but perhaps the concept of firm demography may provide the key to a solution.

Finally, model opportunities are limited to data availability. The data sources collected from different authorities and the data fusions described and planned, however, suggest that for the present study area, an interesting set of (temporal) data is available.

We realise that the present paper does not yet provide much details about the specific models and underlying behavioural principles. The formulation, exploration and estimation of these models and principles will be the next step of the project. Results will be reported in future papers and journal publications.

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