REMOTE SENSING IN URBAN SPRAWL MODELING: SCENARIO AND WAY FORWARD IN DEVELOPING COUNTRIES

Norzailawati Mohd Noor and Alias Abdullah
Urban and Regional Planning Department
Kulliyah Architecture and Environmental Design
International Islamic University Malaysia
P.O Box 10, 50278 Kuala Lumpur
Contact No: +603-61996264 Fax: +603-61964864
Email: norzailawati@iium.edu.my and dralias@iium.edu

ABSTRACT: In recent years, the developing countries was deal the use of computer based models of land use changes and urban sprawl which have greatly increased and tend to become important tools in supporting urban planning and management. The modeling recently used in various planning specialization such as economics, transportation, spatial planning, urbanization, ecology, and other social science aspects. However, modeling sprawl phenomena which convergence to remote sensing data has not fully demonstrated lack of common ground and testable concepts. Remote sensing data products have often been incorporated into urban modeling applications as additional sources of spatial data primarily for historical land use history. The objectives of this study to identify recent scenario and way forward of remote sensing tools in urban sprawl modeling based on reviewed of previously studied and urban planning situation in developing countries and Malaysia contexts specifically.

Keywords: Remote Sensing, Urban Sprawl Modeling, Urban Planning, Developing countries

1. INTRODUCTION

In developing countries, cities of 100,000 or more are expected to triple their built up land area 600,000km^2 in the first three decades of this century. The increasing built-up area by 2.5 times between 2000 and 2030 would expectedly occupy some 500,000 km^2 of land area. Whatever the case, the data proved that developing countries now share the trend of urban sprawl. Specifically, development growth in most developing countries particularly in Malaysia has become a global issue, as rapid expansion process can no longer be controlled. Due to uncontrolled and unmanageable development, the physical, environmental and socio-economic aspects apparently suffered the largest impact.

The planning system has an important role in managing and controlling the development trends and modeling the future scenario was one of methods to guide the decision maker particularly urban planners. Modeling was used in various planning specializations such as economics, transportation, ecology, urbanization and other science social aspects. The main purpose of modeling in urban planning is to help planners to identify and to understand the natural features and the movement in urban systems. In urban sprawl, model has been used to simulate a possible development in the future. This scenario will help planners to estimate the development consequences at local, regional and global stages (Harris & Batty, 2001; Li & Yeh, 2002). Many sprawl models have been implemented previously but the potential of combining with remote sensing techniques has yet not fully assess (Batty & Howe, 2001; Longley & Mesev, 2000; Longley et al, 2001) especially in developing countries.

Previously, the process to provide a development trajectory is conventionally prepared based on field surveying techniques, which are costly and time consuming, particularly when it involves large urban area (Epstein et al., 2002) and this more uneconomical when only updating of selected areas while remote sensing capable to represents a major though still under-used source of urban data, providing spatially consistent coverage of large areas with both high geometric detail and high temporal frequency, including historical time series. Accordingly, this paper attempts to identify recent scenario and way forward for remote sensing tools in urban sprawl modeling based on reviewed of previously studied and urban planning situations in developing countries and Malaysia contexts specifically.

2. MODELING IN URBAN PLANNING

2.1 Sprawl issues in Developing Countries

The space taken up by urban localities is increasingly faster than the urban population itself. Between 200 and 2030, the world urban population is expected to increase by 72 percent, while the built –up areas of cities of 100,000 people or more could increase by 175 percent (UNFPA, 2011), simultaneously effect on developing countries respectively. Among there, China was undergoing the most rapid and largest process of urbanization all over the world (Paulussen, 2003) followed by India and Malaysia.

China is currently experiencing rapid changes mostly noticeable in big cities in terms of economic growth with effects on social, environmental, infrastructure and political systems there. At present the urban population comes up to about 30 % of the Chinese population will increase to more than 50 % in the next 20 years. This tendency will deeply impact the social, environmental and economic situations of the whole country. In India, with an unprecedented population growth and migration, an increased urban population and urbanisation is inadvertent. More and more towns and cities are blooming with a change in the land use along the highways and in the immediate vicinity of the city. This dispersed development outside of compact urban and village centres along highways and in rural countryside is defined as sprawl.

Planning human living environment is obviously complicated. The physical, socio-economic and environmental aspects are particularly of major concerns and should be taken into consideration in the planning process. In Malaysia, the instantaneous emergence of cities with residential, industrial and commercial centre proves that development is growing very fast. Urbanization has increased from 27.6% in 1970 to 65.4% in 2000 and it is projected to achieve 75 % in 2020. In 2001, an area of approximately 3.3% of Malaysia or 437,100 hectare is needed to accommodate an urban population expansion by 2020 (Atan, 2005). The cause to becoming a developed country has faced the country with many difficulties and challenges. Apparently, urban problems in Malaysia are virtually insurmountable with respect to expansion of vicious spiral urban squalor, squatter growth's, congestion and poverty, which in turn are fueled by rural migration and resource exhaustion.

Thus, planning and managing the urban areas have become the utmost tasks in dealing with issues and problems due to the tremendous development growth. At present, the advancement of geo-information technology and modeling have considerably affected the dynamic nature of urban and regional planning in Malaysia and consequently improved decision making, planning and management concerning urban areas. The Town and Country Planning Act, 1976 (Act 172) with its latest amendment in year 2001, manifested the concern of adopting the Geographical Information System in the planning process, especially in the preparation of development plans. Indeed the convergence of remote sensing, GIS and database management system has helped in quantifying monitoring and modeling subsequently on the sprawl process.

2.2 Modeling Concepts In Urban Sprawl

The evolution of computer information technology over the last few decades has had a significant impact on the planning profession. Modeling through computation was accepted as part of rational planning. These strongly support the requirement of computer-aided techniques in the planning process. According to the planning projection, the needs of other planning statistic such as population, employment, housing information and etc is crucial in determining the emergence of land use movement as they linked together, before the full significance of land use is noticeable.

Models have been used consistently in urban planning in early 1960s. The Lowry model (Lowry, 1964) which studied of relationship of land use and transportation in land use types contexts. Previously, the planning model such as Herbert and Steven that used a linear programming (Herbet and Steven, 1960), TOPAZ (Technique for Optimal Placement and activities zones) by Brotchie (1969) and Koopsman & Beckman for determination of land use analysis. (Koopsman and Beckman, 1957). Many planning models that exist before 1970s tend to study the planning and transportation. In early 1970s, the development of model in planning has been influence by other aspect such economic (Mills, 1972) with simulation model NBER (National Bureau of Economic Research) by Ingram, 1972 and planning administration of policy evaluation (Batty 1976 and Puttman, 1976). The other model was including the Forrester urban movement model (Forrester and Fournier, 1979) and CARPE that studied of growth impact (Laudet and Fournies, 1979).

In urban sprawl modeling studies, the spatial phenomenon is simulated geometrically using techniques of cellular automata (CA). (Clarke, et al., 2002; Torrens and Sullivan, 2001). The inadequacy in some of these is that the models fail to interact with the causal factors driving the sprawl such as the population growth, availability of land and proximity to city centres and highway. Cheng and Masser (2003) report the spatial logistic regression technique used for analysing the urban growth pattern and subsequently model the same for a city in China. Their study also includes extensive exploratory data analyses considering the causal factors. The inadequacies in these were to accurately pinpoint spatially where the sprawl would occur. The approaches from developing countries context were developed by (Yeh and Li, 2001; Cheng and Masser, 2003) for China, (Jothimani, 1997 and Lata et al, 2001) for India and Malaysia by (Mazlan and Mohd Noor , 2011 and Mohd Noor and Hashim, 2009).

3. TOWARDS REMOTE SENSING IN URBAN MODELING

In urban modeling, a good model and good theory require the incorporation of multiscale dynamics. In relation, the building, dynamics and applying models that accurately describe urban dynamics as revealed by the time series remote sensing data quickly becoming an imperative for understanding the complexities of urban sprawl (Longley and Mesev, 2000; Irwin and Geoghegan, 2001). The great strength of remote sensing is that it can provide spatially consistent data sets that cover large areas with both high detail and high temporal frequency, including historical time series. Mapping of urban areas has been accomplished at different spatial scales, e.g with different spatial resolutions, varying regional studies are often focused on mapping just the extent of urban areas. These techniques have advantages in characterizing the spatiotemporal trends of urban sprawl using multi-stage images, providing a basis for projecting future sprawl processes in urban areas. In this relation, this technology was cost effective and efficient to use in urban sprawl analysis (Radeloff et al, 2000; Sutton, 2003; Sudhira et al., 2004 and Yang & Liu, 2005).

In urban sprawl, remote sensing datasets provides a useful information of sprawl features and generating a sprawl models for decision maker (Clarke et al, 2002; Torrens & Alberti, 2000). These also have been used for observation, monitoring and mapping of land use sprawl. Commonly these datasets have been combined with GIS to bring a sprawl model. According Townshend (1977), the remote sensing attributes particularly used to choose image for movement process in each urban system based on; i) rapid changes on large objects in urban area tend to used low resolution and high frequency, ii) rapid changes on small objects in urban area tend to used high resolution and high frequency data, iii) slow changes on large objects tend to used low resolution and low frequency data, iv) slow changes on small object tend to used high resolution and low frequency data.

In accordance, there are five different areas in which remote sensing combined with spatial analysis can support urban modeling (Herold, 2005). Based on the basic mapping and model requirement, remote sensing data have served the needs of many model applications as source of spatially consistent and timely data. The spatial arrangement and configuration of the basic elements (tone and color) combine to give higher order interpretation features of greater complexity such as size, shape and texture or pattern and association, that are significant and characteristic for urban areas and urban land use (Bowden, 1975; Haack et al., 1997).

4. THE CHALLENGES OF REMOTE SENSING IN URBAN SPRAWL MODELING

Research regarding urban sprawl modeling lack common ground and testable concept particularly in Malaysia. The main concern here is how to implement remote sensing data to support urban sprawl modeling the challenges some urban remote sensing projects generated data and statistics based on jurisdiction, but failed to justify how to effectively link the data to pattern analysis of urbanization across jurisdiction levels. Such information can support policymaking in urban planning and natural resource conservation. There are some issues facing urban remote sensing research which addressed such as stated by Herold et al 2003, many urban remote sensing studies tend to focus on technical issues in data assembly and physical image classification rather than on the use of the mapped by-products in the spatio-temporal analysis of urban regions.

Although the best way to measure sprawl might be from an airplane using sophisticated remote sensing imagery and complex GIS, these technological reliant methodologies are limited by problems of scale and financial cost. A basic difficulty these efforts encounter relates to the indistinct demarcation between urban and rural areas on the edges of cities. Remote sensing provides an additional source of information that more closely respects the actual physical extent of a city based on land cover characteristic (Weber,2001). However, the definition of urban extent still remains problematic and individual studies must determine their own rules for differentiating urban from rural land.

Most local scale remote sensing applications require intra-urban discrimination of land cover and land use types. Considering the land cover heterogeneity of the urban environment several studies have shown that a spatial sensor resolution of at least 5m is necessary to accurately acquire the land cover objects (especially the built structures) in urban areas (Welch, 1982 Woodcock & Strahler, 1987). The traditional remote sensing objectives emphasizing the technical aspects of data assembly and physical image classification should be augmented by more inter-disciplinary and application –oriented approaches. Research should focus on the description and analysis of spatial and temporal distributions and dynamics of urban phenomena, in particular urban land use changes. However, there is still a lot of resistance, especially among social scientist, against using remote sensing techniques in urban studies. There are several reason such as 1) there is a general concern about pixelizing the social environment, i.e., focusing too much on the physical aspect of urban areas at the expense of social issues. Indeed, the socioeconomic variables of interest are usually not directly visible from measurements taken from remote sensing observation. Secondly, the social issues outside of geography and planning are generally more concerned with why things happen rather than where they happen, and accordingly, most social scientist tend to underestimate the value of the detailed spatial data that remote sensing provides. It is not appreciated that remote sensing can provide useful additional data and information for social science oriented studies, e.g by quantifying the spatial context of social phenomena and by measuring socially induced spatial phenomena as these evolve over time, for example, by helping make connection across level of analysis and between different spatial and temporal scale, remote sensing has the potential to provide additional levels of information about the links between land use and infrastructure change and variety of social, economic and demographic processes.

In terms of analyzing urban growth specifically in sprawl patterns, Batty and Howes (2001) believe that remote sensing technology, especially considering the recent improvements mentioned above, can provide a unique perspective on growth and land use change processes. Datasets obtained through remote sensing are consistent over great areas and over time, and provide information at a great variety of geographic scales. The information derived from remote sensing can help describe and model the urban environment, leading to an improved understanding (Herold, 2005).

5. OUTLOOK AND CONCLUSION

Remote sensing has proven to be an invaluable tool to support sprawl modeling as an alternative solution to urban planning problems in developing countries. Thus far, the justification for using remote sensing to support and improve urban sprawl modeling has been presented. The understanding urban dynamic based on actual measurement from remote sensing in the context of existing and evolving urban modeling remains challenging. Despite the promise of new sensors and technologies, this study still perceive a gap between the academic, research-focused results offered by the remote sensing in urban sprawl modeling also the academic data and products by government bodies of urban cities and region. Based on the previous studies there some problems must be overcome in order to develop useful application in terms of skills and integration of geospatial data. The contribution in the form of understanding regarding planning contexts with this approach is potentially rewarding and uniquely insightful. Through the use of remote sensing, the spatial evolution of urban systems can be better described, measured and modeled.

In conclusion, various study positively proved the combination application of remote sensing tools and urban modeling to support analysis of urban sprawl in variety different ways. However, the research is still at an early stage and relies heavily on current scenario of decision makers in each member in developing countries specifically to unite the expertise and executing agencies in confronting the problems and exploring the value of the tools in the context of both urban theory and specific application.

6. REFERENCES

Atan, M. M. J. (2005). Rancangan Fizikal Negara; Pelaksanaan dan Pemantauan, *Senior Planners Meeting, Jabatan Perancangan Bandar dan Desa, Malaysia,* Julai 25-26. Penang, Malaysia.

Batty, M., (1976). Urban Modelling. Cambridge University Press, London.

Batty, M., & Howes, D. (2001). Predicting temporal patterns in urban development from remote imagery. In J. P. Donnay, M. J. Barnsley, & P. A. Longley (Eds.), Remote sensing and urban analysis (pp. 185–204). London and New York: Taylor and Francis.

Bowden, L. W. (1975). Urban environments: inventory and analysis. In L. W. Bowden et al. (Eds.), Manual of remote sensing, vol. 2 (1st ed., pp. 1815–1880).

Brotchie, 1969. J.F. Brotchie, A general planning model. *Management Science (Theory)* **10** (1969), p. 265

Cheng, J., dan Masser, I., (2003). Urban growth pattern modeling: a case study of Wuhan City, PR China, Landscape Urban Plan.62, ms.199-217

Clarke, K. C., Parks, B. O., & Crane, M. P. (2002). Geographic information systems and environmental modeling. New Jersey: Prentice Hall.

Durieuxa L, Erwann Lagabrielle, Andrew Nelson (2008). A method for monitoring building construction in urban sprawl areas using object-based analysis of Spot 5 images and existing GIS data. ISPRS Journal of Photogrammetry & Remote Sensing

Epstein, J., Payne, K., Kramer, E., (2002). Techniques for mapping suburban sprawl. Photogr. Eng. Remote Sens. 63 (9), 913–918.

Haack, B. N., Guptill, S. C., Holz, R. K., Jampoler, S. M., Jensen, J. R., & Welch, R. A. (1997). Urban analysis and planning. In Philipson et al. (Eds.), Manual of photographic interpretation (2nd ed., pp.517–554).

Harris, B. and Batty, M. (2001). Location Models, Geographic Information and Planning Support Systems, in Brail, R.K and Klosterman, R.E (eds) Planning Support Systems, ESRI Press, California pp. 25-57.

Herbert, J. D. and Benjamin Stevens, A Model for the Distribution of Residential Activity in Urban Areas," Journal of Regional Science, 2 pp. 21-39 1960.

Herold M., Couclelis dam Clarke K.C (2005). The role of spatial metrics analysis and modeling of urban land use change. Computers, Environment and urban system.Vol29 pg 369-399

He.,C., Okada.,N., Zhang., Q., Shi., P., dan Li., J (2008). Modelling dynamic urban expansion incorporating a potential model with cellular automata. Landscape and urban planning 86, ms 79-91.

Herold, M., Goldstein, N. C., & Clarke, K. C. (2003). The spatiotemporal form of urban growth: measurement,analysis and modeling. Remote Sensing of the Environment, 86, 286–302.

Irwin, E., Geoghegan, J., 2001. Theory, data, methods: developing spatially-explicit economic models of land use change. Agric. Ecosyst. Environ. 85, 7–24.

Jacquin, A., Misakova, L., and Gay.M (2008). A hybrid object-based classification approach for mapping urban sprawl in periurban environment, Landscape and Urban Planning Vol 84 (2007) pp 152-165.

Jothimani, P., (1997). Operational urban sprawl monitoring using satellite remote sensing: excerpts from studies of ahmedabad, Vadodara and Surat, Indi. Paper presented at 18th Asian Conference on Remote sensing held during October 20-24, 1997, Malaysia.

Koopmans, T. and Beckman, M., 1957. Asignment Problems and the Location of Economic Activities, Econometrica, 25, 53-76.

Lata K. M., Sankar Rao C. H., Krishna Prasad V., Badrinath K. V. S., Raghavaswamy, 2001. “Measuring urban sprawl: a case study of Hyderabad”, GISdevelopment, Vol. 5(12).

Longley P. and V. Mesev.(2000) "On the measurement and generalisation of urban form" *Environment and Planning A* 32(3), 2000, pp. 473–488.

Lowry, I.S (1964). A Model of Metropolis, RM-4035-RC, The Rand Corporation, Santa Monica.

Li, X., Yeh, A., 2002. Neural-network-based cellular automata for simulating multiple land use changes using GIS. Int. J. Geogr. Inform. Sci. 16, 323–343.

Liu, X.H., dan Anderson, C., (2004). Assessing the impact of temporal dynamics on land use change modeling. Computers, environment and urban systems, Volume 28, pp.107-124

Longley, P. A., Barnsley, M. J., & Donnay, J. P. (2001). Remote sensing and urban analysis: a research agenda. In J. P. Donnay, M. J. Barnsley, & P. A. Longley (Eds.), Remote sensing and urban analysis (pp. 245–258). London and New York: Taylor and Francis

Mazlan, H; Mohd Noor,N and Marghany, M (2011). Modeling sprawl of un-authorized development using

Geospatial Technology: Case Study in Kuantan District, Malaysia. *International Journal of Digital Earth*, 1753-8955, Volume 4, Issue 3, First published 2011, Pages 223 – 238

Mills, E.S., (1972). Studies in the structure of the urban economy, Johns Hopkins Press, Baltimore, MD.

Mohd Noor, N. dan Hashim, M. (2009). Modelling un-authorized Land Use Sprawl with Integrated Remote Sensing-GIS Technique and Cellular Automata. *ICCSA 2009, Part I, LNCS 5592:*163-175. Jun, 29 – Julai, 2. Springer - Verlag Heidelberg, Berlin.

Paulussen, J (2003).Managing Eco-Development by Regional Planning: Task, Instrumen & Application. Proceeding of the internet Conference on Ecocity Development.

Putman, S.H., (1973). The interrelationships of transportation development and land development, Urban Planning Division, Federal Highway Administartion, US, Department of Transportation, Washington.

Radelhoff, V.C., Hapen, A.E., Voss, P.R., Field, D.R., Mladenhoff, D.V., (2000). Exploring the spatial relationships between census and land cover data. Soc.Nat. Resour. 13 (6), 599–609.

Sudhira, H. S., Ramachandra, T.V. and Jagadish, K.S. (2004) Urban sprawl: metrics, dynamics and modelling using GIS, International Journal of Applied Earth Observation and Geoinformation Vol. 5, No. 1, 29-39.

Sutton, P. A. (2003). Scale-adjusted Measure of “Urban Sprawl” using Nighttime Satellite Imagery. *Remote Sens. Environ.* 86 (3), 370–384.

Torrens, P. dan O`Sullivans, D (2001). Cellular automata and urban simulation: where do we go from here? Editorial Environment and Planning B: Planning and Design, Vol 28, pp.163-168

Torrens P. M., and Alberti M., 2000. “Measuring sprawl”, Working paper no. 27, Centre for Advanced Spatial Analysis, University College London.

Townshend, J.R.G. (1977). A framework for monitoring the environment through the use of remote sensing. In Van Genderen, J.L. and Collins, W.G. (eds.) Monitoring Environmental Change by Remote Sensing, Remote Sensing Society, Reading, UK, pp.1-5.

UNFPA (2011).State of world population 2007.Unleashing the potential of urban growth.Http//www.unfpa.org/swp/2007/English/chapter_4.html.(access on June 13th 2011).

Weber, C. (2001). Remote sensing data used for urban agglomeration delimitation. In J. P. Donnay, M. J.Barnsley, & P. A. Longley (Eds.), Remote sensing and urban analysis (pp. 155–167). London and New York: Taylor and Francis.

Welch, R. (1982). Spatial resolution requirements for urban studies. International Journal of Remote Sensing, 3(2), 139–146.

Woodcock, C. E., & Strahler, A. H. (1987). The factor scale in remote sensing. Remote Sensing of Environment, 21, 311–332.

Yeh, A G-O and Li, X. (2001). A constrained CA model for the simulation and planning of sustainable urban forms by using GIS. Environment and Planning B: Planning and Design, 28, pp.733-753.

Yin L.(2005). Assessing Ex-Urban Residential Markets: An Agent-Based Model. Paper Extracted From Proceedings Of The Agent 2005 Conference On Generative Social Processes, Models, And Mechanisms, Anl/Dis-06-5, Isbn 0-9679168-6-0, C.M. Macal, M.J. North, And D. Sallach (Editors), Co-Sponsored By Argonne National Laboratory And The University Of Chicago, October 13−15, 2005.