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An Environmental Assessment Model for Knowledge-Based Urban Development

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Structured Abstract

Purpose – In recent years, knowledge-based urban development (KBUD) has introduced as a new strategic development approach for the regeneration of industrial cities. It aims to create a knowledge city consists of planning strategies, IT networks and infrastructures that achieved through supporting the continuous creation, sharing, evaluation, renewal and update of knowledge. Improving urban amenities and ecosystem services by creating sustainable urban environment is one of the fundamental components for KBUD. In this context, environmental assessment plays an important role in adjusting urban environment and economic development towards a sustainable way. The purpose of this paper is to present the role of assessment tools for environmental decision making process of knowledge cities.

Design/methodology/approach – The paper proposes a new assessment tool to figure a template of a decision support system which will enable to evaluate the possible environmental impacts in an existing and future urban context. The paper presents the methodology of the proposed model named 'ASSURE' which consists of four main phases.

Originality/value –The proposed model provides a useful guidance to evaluate the urban development and its environmental impacts to achieve sustainable knowledge-based urban futures.

Practical implications – The proposed model will be an innovative approach to provide the resilience and function of urban natural systems secure against the environmental changes while maintaining the economic development of cities.

Keywords – Knowledge-Based Urban Development, Environmental Assessment.

Paper type – Academic Research Paper

1 Introduction

Earth's environment has changed at local (air, soil, and water pollution), regional (greenhouse effect, land degradation) and global (climate change, loss of biodiversity) scales over the last-half century. The atmospheric concentrations and distributions of greenhouse gases, aerosols and their radiative forcing have changed by human activities (IPCC, 1996). Water quality and soil fertility in many regions of the world have been severely degraded due to population growth and the biotic system has been altered, depleted and endangered by increasing human demands (Ojima et al., 1994). As a consequence of globalisation, cities become engines of population, economic growth and innovative improvements. As stated by Yigitcanlar and Velibeyoglu (2008), rapid urbanisation and its immense effects on the environment have raised the importance of urban sustainability, and necessity of the need to adjust urban and economic development in the knowledge era.

While developing knowledge-based development strategies, it is important to provide a good quality of life with various lifestyle options in a healthy and physically attractive environment (Yigitcanlar et al., 2007). A knowledge-based approach needs to be environmentally sustainable and, therefore, requires holistic environmental sustainability assessment to monitor the urban metabolism and help the decision-making authorities and actors to control it. This paper presents the role of assessment tools for environmental decision making process of knowledge cities. This paper also introduces a new assessment tool (ASSURE) to figure a template of a decision support system which will enable to evaluate the possible environmental impacts in an existing and future urban context. Additionally, it will be an innovative approach to provide the resilience and function of urban natural systems secure against the environmental changes while maintaining the economic development of cities.

2 Knowledge Cities and Sustainable Urban Ecosystems

Even though cities are the 'engines' for economic development, the impacts of rapid urbanisation and industrialisation provide a threat to the health of human beings, as well as environmental quality and productivity. As a result, knowledge city is introduced as a new strategic development approach for the regeneration of industrial cities. Knowledge city defined as a city designed to support the nurturing of knowledge towards the aspects of social, economic and cultural life of the city. A city which knowledge is accessible to all citizens through a network of communication technologies, public libraries, schools, civic centres and cultural services that is available to other cities' citizens (Edvinsson, 2003; Barcelona City, 2003). It aims to upgrade institutional and organisational capacities while creating innovative, educational, creative and adaptable environments (Knight, 1995).

As society becomes increasingly knowledge-based, the natural environment of the city changes due to economic activities required different conditions and environments (Knight, 1995). While nations develop technologically, their level of consumption and waste increase, their ecological footprints expand due to their advanced economies. Economy is a self-regulating mechanism which produces energy consumption and material flow of ecological services. These services are called natural capital and they are generated by human-made capital which refers to factories, buildings, roads and other physical artefacts. Each of them demands an environment of space for shelter, reproduction and waste assimilation. However, the degradation of environment and its services are irreversible and no type of human-made capital can substitute for them. In this sense, there is a need to balance the increasing human demands on the natural systems (Rees, 1992; Cleveland, 2003).

Environmental sustainability has strong relations with the foundation stones of knowledge city formation in terms of providing urban diversity, social equity, sustainable communities and urban ecosystems (Yigitcanlar et al., 2008). A sustainable urban ecosystem manages its natural resources in a "closed loop" by minimizing the risk of environmental damage while controlling flows of resources and reduces its energy, materials and information losses. It ensures environmental justice in the shared use of urban ecosystems while balancing environmental quality against resource use (Mourao & Cuchi, 2007). Examining the city as an ecosystem enables to investigate the flows of energy and material in the ecological systems along with the interactions between human and non-human parts of the system (Alberti, 2008). Because change is an inevitable result of human activities, the capacity of urban ecosystems to respond and adapt these changes is an important factor to take into consideration in creating environmentally sustainable knowledge city.

3 Indicator-Based Environmental Assessment

Improving urban amenities and ecosystem services by creating sustainable urban environment is one of the fundamental components for knowledge-based urban development (KBUD). In this context, environmental assessment tools play an important role in adjusting urban environment and economic development towards a sustainable way. They support KBUD by providing several functions. They define the current environmental situation of an urban area by assessing the impacts of economic and social development pressures on natural resources. They provide environmental data to explore the areas which have particular ecological characteristics that need to be protected. Furthermore, they assess the probable effects of proposed plans on the quality of urban environment and makes comparisons with the effects of alternative options (RCEP, 2002).

Environmental assessment is performed by applying different approaches and tools ranging from indicators to comprehensive models. An environmental indicator, as defined by US Environmental Protection Agency (2010), is a numerical value based on quantitative measurements or statistics of environmental condition that are tracked over time at a wide variety of geographic scales from local to regional and national levels. Environmental indicators are powerful tools for assessing the environmental impact of human activities, highlighting emerging problems and revising the effectiveness of current policies. They are considered as a subset of sustainable development indicators which are meant to help policy makers in decision-making, benchmarking for environmental performance and monitoring progress or changes in environmental systems to implement improvements or for policy making (Giannetti et. al., 2009).

Recent years, an increasing number of environmental assessment tools have been developed to track and measure the sustainability of urban environment. Although they are derived from different indicator datasets, their common framework is based on addressing these questions: (1) What is happening to the state of natural resources; (2) Why is it happening, and; (3) What is being done about it. Environmental assessment provides a basis to assess status and trends in ecological systems and diagnose the causes of the problems across a wide range of spatial scales. It also helps to assist local and national policymakers to improve their action towards sustainability. Briefly, the city considered as an urban ecosystem requires a holistic environmental assessment tool to monitor the urban metabolism and help the decision-making authorities and actors to control it (Alberti, 1996; Dakhia & Berezowska-Azzag, 2010).

4 The ASSURE Model

The city as a place where 'nature and artifice meet' (Lévi-Strauss, 1961), is a dynamic biological organism consists of people, built-up environment and infrastructure that are highly dependent on nature. To understand the interactions between urban development and environmental change we need to consider cities as heterogeneous ecosystems with its biological and physical complexities which are all interacting with each other (Alberti, 1999; Cadenasso & Pickett, 2008). When we look at the structure of an urban ecosystem, human behaviours are the major determinant on the ecosystem dynamics. They directly influence the biodiversity of land and the consumption of resources in an irreversible way. The most important human impact on the physical environment is land use and land cover change by increasing impervious surface areas. Imperviousness represents the imprint of land development on natural landscapes. In this context, impervious surface is a key environmental indicator for monitoring the sustainability of urban ecosystems (Schueler, 1994; Brabec et. al., 2002).

The focus of this study is to evaluate the relationship between the impervious surfaces and natural environment by measuring the carrying capacity of resources. In this context, the study aims to investigate the impacts of land cover change on urban ecosystems by developing a micro-scale index model to assess their indirect or consequential effects for environmental sustainability. Proposed model is entitled 'ASsessing the Sustainability of URban Ecosystems (ASSURE)'. The structure of the ASSURE model is illustrated in Figure 1 below. The model is developed by following four steps: theoretical framework; indicator selection; model development; model testing and policy development. These parts of the model will be explored in more detail below.

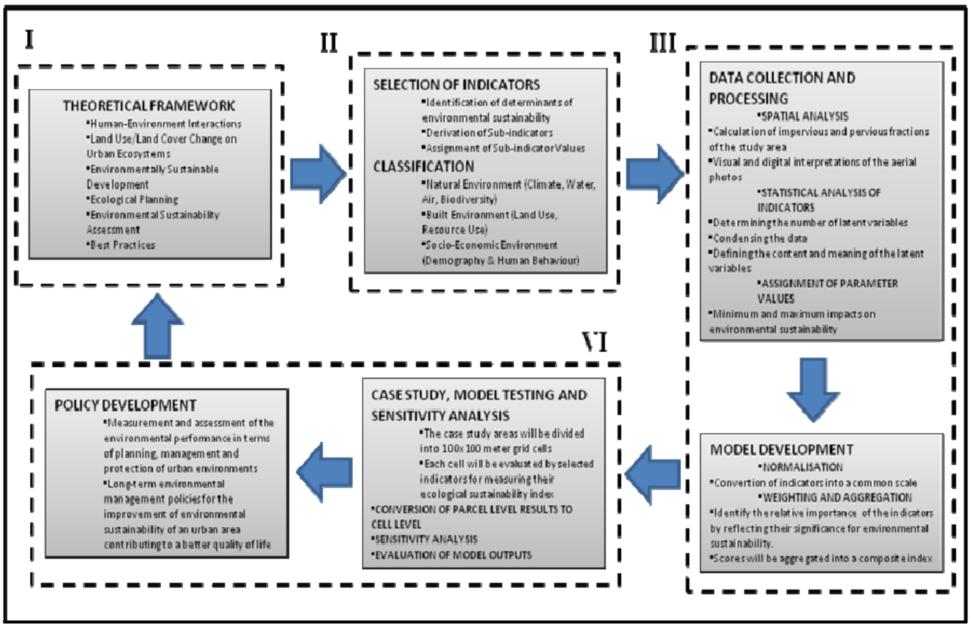

Figure 1. Structure of the ASSURE Model

4.1 Theoretical Framework

Humans affect urban ecosystems at extraordinary rates through alteration of land and resource consumption. These effects are both obvious (e.g. Pavement) and subtle (e.g. Conversion of forest to agriculture and then to suburbs, acid rain), both immediate (e.g. Dams drown river valleys) and long term (e.g. New intercity highways promote city growth on 20 to 100 year scales) (Alberti et al. 2003). Therefore, environmental sustainable development becomes an essential vehicle in order to protect and enhance the environmental conditions of urban ecosystems. The concept of environmentally sustainable development (ESD) which is defined as 'the integration of human activities into natural systems with ensuring the long-term sustainability of these systems' constitutes the theoretical framework of the model. As a subset of sustainable development, ESD ensures environmental justice in the shared use of urban ecosystems while balancing environmental quality against resource use (Weiland, 2000). The objectives of ESD are; (1) to enhance the economic development by safeguarding the welfare of future generations, (2) to provide the equity within and between generations and (3) to protect biological diversity by preserving essential ecological processes and life support systems (Commonwealth of Australia, 1992). As the dependent variable of the model, ESD will be used to evaluate environmental performance at a given area based on some indicator sets. Furthermore, it will provide decision-making support for establishing sustainable development strategies

4.2 Indicator Selection

As shown in Table 1, the indicator base of the model has been divided into three main categories regarding human, built and natural components of the urban ecosystems. These three categories are separated into 9 indicator sets and 26 indicators.

Table 1. Selected Indicators of the ASSURE Model

CATEGORIES	INDICATOR SET	INDICATORS
NATURAL ENVIRONMENT	**CLIMATE**	Temperature
		Evapotranspiration
		Precipitation
	WATER	Stormwater Runoff
		Infiltration
		Water Pollution
	AIR	Air Pollutant Emissions
		Noise Pollution
	BIODIVERSITY	Threatened Flora
		Threatened Fauna
BUILT ENVIRONMENT	**RESOURCE USE**	Energy Consumption
		Water Consumption
		Waste Generation
	LAND USE & TRANSPORT	Street Connectivity
		Vehicle Kilometres Travelled
		Mode Of Transport
		Frequency Of Trips
		Proximity To Public Transport
		Car Ownership
SOCIO-ECONOMIC ENVIRONMENT	**DEMOGRAPHY**	Population Density
		Age
		Immigration Status
	SOCIAL STRATIFICATION	Disposable Income
		Education
	LIFESTYLE BEHAVIOR	Family Size
		Marriage Status

In terms of natural environment, impervious surfaces have negative impacts on human comfort and health in terms of decreased precipitation and evapotranspiration rates as well as increased surface temperatures. Built and paved surfaces impede rainwater infiltration and groundwater recharge that leads to increased stormwater runoff and pollutant load carried by stormwater into the waterways. Land cover change results in the form of air pollutant emissions from transport activity and noise pollution emitted by transportation systems. Furthermore, built environment directly affects habitats and ecosystems through consumption, fragmentation, and replacement of natural cover with impervious surfaces. The extent of land development, the type of development and the location of infrastructure have direct and long-lasting implications for ecosystems.

In terms of built environment, private households make significant contributions to environmental sustainability in terms of resource consumption. As impervious surfaces collect solar heat in their dense mass, they raise air temperatures which lead to increased energy consumption resulting from the lighting, heating, and cooling of the buildings, water consumption and domestic wastes. Increased consumption of resources leads to increased demand for human needs and more intensive use of land. New dwellings bring about the development of large commercial and industrial areas as well as roads, utilities and other infrastructure. As development becomes more dispersed with increasing numbers of families living on large lots at the urban fringes and as jobs and housing become increasingly segregated from one another distances between destinations have increased. People are forced to make more trips by car which creates environmental problems including: greenhouse gas emissions, increased traffic noise and upstream impacts from activities associated with vehicle use.

In terms of socio-economic environment, accelerating rates of land cover change is associated with increased population densities within the region. This development has a negative effect on vegetation cover as land is cleared to support more people and infrastructure. The urban vegetation is associated with the social stratification among urban neighbourhoods in terms of disposable income and education levels. High income and higher education level have a positive relationship with vegetation cover due to a number of reasons such as ability to maintain elaborate gardens, migrate to desirable green areas, contribute to community green-space projects and reflect the level of knowledge of the environment and environmental problems. Lastly, researchers have found that lifestyle behaviour is an important predictor of land cover change indicating that household patterns of consumption and expenditure on environmentally relevant goods and services are motivated by group identity and perceptions of social status associated with different lifestyles.

The indicator sets of the index model need to be flexible enough to respond to the different needs of urban environment and trends of development at the different levels and scales of the urban system (Li et al., 2009). The validity, interpretability, and explanatory power of the index model depend on the availability and quality of the environmental data. Environmental data are difficult to come by compared to data for economic and social indicators. As environmental issues are complex and problems are multifaceted, it is virtually impossible to monitor and measure every aspect of the environment. Assessment and evaluation of environmental data is the combination and comparison of information that is often subjective and not able to be measured. For this study, data collection can be a major problem due to unavailability of data at parcel level. It should be emphasised that, for some indicators, the data will be provided by Census Collection District (CCD) level and then will be transferred into parcel level by a disaggregated method.

4.3 Model Development

Monitoring of ecosystem or resource management requires a comprehensive data about the characteristics of a specific urban environment. Many of the existing environmental indices measure the sustainability of environment on macro-scales (national, regional, international). They may lead to an understanding of the general situation but may not be representative of a smaller area. Thus, the proposed environmental index model will give an opportunity to investigate the situation by doing observations on a micro-scale (parcel level) which brings out the general picture of the environmental problems.

The spatial analysis is the first phase of the proposed model. The main purpose of this phase is to estimate impervious and pervious fractions of the study area based on surface measurement that will be carried out through remote sensing data. At this stage, different type of land surfaces (such as paved, vegetated, water) will be evaluated by using satellite imagery. From visual and digital interpretations of the aerial photos, the total area of each land cover type within parcel will be measured. Then, all measured surfaces in the parcel blocks and surrounded roads will be summed up in order to give the total surface area in the border of a grid cell (Figure 2).

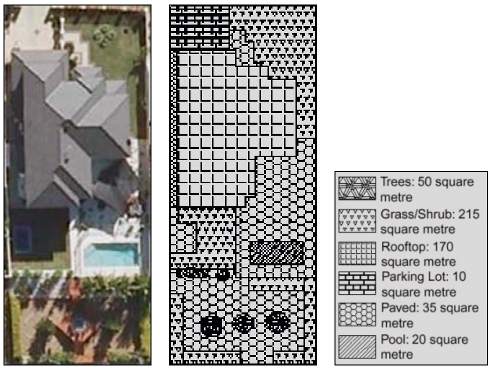

Figure 2. An Example of a Surface Measurement in a Parcel

In order to clarify the relationship between indicators, at the next step statistical analysis will be used for data reduction and correlation analysis. This step will assess the accuracy of the data set and provide an understanding of the implications of the methodological processes (e.g. weighting and aggregation) during the construction phase of the model. It designates whether the nested structure of the composite indicator is well defined and the set of available individual indicators is sufficient or appropriate to describe the phenomenon. At the next stage, parameter values of indicators will be allocated in terms of their minimum and maximum impacts on environmental sustainability. Parameter values will be assigned by reviewing various studies in the literature. However, for some indicators, it is inevitably hard to define parameters related to literature review. Therefore, expert survey will be conducted for the parametric classification of these indicators. Expert survey is a widely used method for gathering data from respondents within their domain of expertise in order to gain judgments on complex matters where precise information is unavailable. Expert survey will provide a rating for each indicator regarding its ‘environmental sustainability value’ on different land cover types using a scale from 1 to 10. Respondents will be asked to designate a score between 1 and 10 which a value of 0 refers to the poorest level and 10 refer to the highest level.

Indicators are expressed in a variety of statistical units, ranges or scales. Normalisation is necessary to remove the scale effects of different units of measurement which cannot be integrated equally into the indicator framework in their original mode. There are a number of normalisation methods available such as ranking, standardisation, re-scaling, categorical scales, indicators above or below the mean and so on. The normalisation method should take into account the data properties and the objectives of the composite indicator. The issues that could guide the selection of the normalisation method include whether: (1) hard or soft data are available, (2) exceptional behaviour needs to be rewarded/penalised, (3) information on absolute levels matters, (4) benchmarking against a reference country is requested, and (5) the variance in the indicators needs to be accounted for (Nardo et al., 2005). Before weighting and aggregation procedures, the values of each indicator will be normalised to render them comparable. Then, different weights will be assigned to indicators in order to identify their relative importance in the model by reflecting their significance for environmental sustainability. After weighting scores have been assigned to each indicator, these scores will be aggregated into a composite index. Lastly, a sensitivity analysis should be undertaken to assess the robustness of the index in terms of the mechanism for including or excluding single indicators, the normalisation scheme, the imputation of missing data, the choice of weights and the aggregation method (OECD, 2008).

4.4 Model Testing and Policy Development

In order to test the performance of the model, Gold Coast City in Australia has been selected as the case study for this research. The model will be piloted within a particular area in order to test the capabilities and accuracy of the model. After piloting, the model will be recalibrated and applied in a number of suburbs of the Gold Coast. The case study areas will be divided into 100x100 meter grid cells. Each surface type in the parcel will be evaluated by selected weighted indicators for measuring their environmental sustainability. Then, these values of all indicators will be transferred into grid cells in a Likert scale from 0 (low) to 5 (high) that is indicating the sustainability level of each grid cell. A composite sustainability map will be prepared for all indicators produced by the GIS-based model. Figure 3 illustrates an example composite sustainability index structure of the GIS-based model. The findings of the testing and analysis process will be used to develop long-term environmental management policies for the improvement of environmental sustainability of an urban area contributing to a better quality of life. The proposed model will be a valuable tool to assist municipal authorities to measure and report on their environmental performance in terms of planning, management and protection of urban environments.

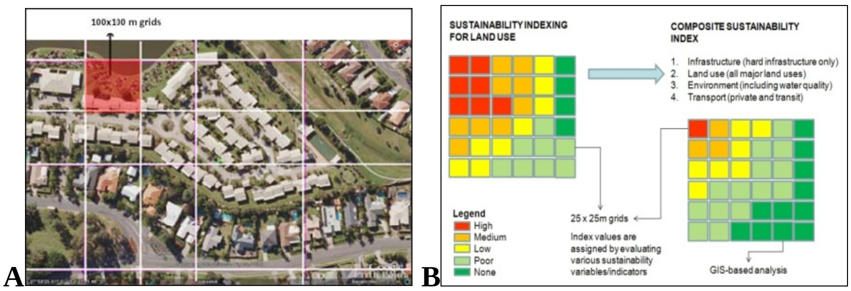

Figure 3. (A) An Example of 100x100 meter grid cell (B) An Example of Composite Sustainability Index

5 Conclusion

In recent years, knowledge-based development has resulted in many successful stories in transforming an industrial city to a socially, culturally, and economically sustainable knowledge city. This study will contribute practically by providing an environmental sustainability assessment tool that will be used for the decision-making process in KBUD. The proposed model will be a useful guidance to evaluate the urban development and its environmental impacts to achieve a sustainable urban future. It will provide long-term environmental, economic and social benefits for cities. Environmentally, implementation of the model creates ecologically effective green areas, reduces ecological risks, and improves the quality of water, air and soil. Economically, it prevents urban sprawl and traffic congestion, provides better utilisation of existing infrastructure. Socially, it reduces health risks, improves the quality of urban life and city services (e.g. health, education, transportation, recreation). With all these benefits, this research will provide further opportunities in turning unsustainable problematic urban areas into potential sustainable urban ecosystems.

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