Towards sustainable urban futures: evaluating urban sustainability performance of the Gold Coast, Australia

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ABSTRACT:

Creating sustainable urban environments is one of the challenging issues that need a clear vision and implementation strategies involving changes in governmental values and decision making process for local governments. Particularly, internalisation of environmental externalities of daily urban activities (e.g. manufacturing, transportation and so on) has immense importance for which local policies are formulated to provide better living conditions for the people inhabiting urban areas. Even if environmental problems are defined succinctly by various stakeholders, complicated nature of sustainability issues demand a structured evaluation strategy and well-defined sustainability parameters for efficient and effective policy making. Following this reasoning, this study involves assessment of sustainability performance of urban settings mainly focussing on environmental problems caused by rapid urban expansion and transformation. By taking into account land-use and transportation interaction, it tries to reveal how future urban developments would alter daily urban travel behaviour of people and affect the urban and natural environments. The paper introduces a grid-based indexing method developed for this research and trailed as a GIS-based decision support tool to analyse and model selected spatial and aspatial indicators of sustainability in the Gold Coast. This process reveals parameters of site specific relationship among selected indicators that are used to evaluate index-based performance characteristics of the area. The evaluation is made through an embedded decision support module by assigning relative weights to indicators. Resolution of selected grid-based unit of analysis provides insights about service level of projected urban development proposals at a disaggregate level, such as accessibility to transportation and urban services, and pollution. The paper concludes by discussing the findings including the capacity of the decision support system to assist decision-makers in determining problematic areas and developing intervention policies for sustainable outcomes of future developments.

Keywords: sustainable urban development, planning decision support systems, geographic information systems, spatial indexing

Introduction

As growing population, immigration from rural areas to cities and changing consumption pattern of the people are considered, expansion of urban areas and current unsustainable lifestyle qualities of people will still be top considerations of academic and political agendas. Population growth and urbanisation are necessary parts of effective and efficient economic growth policy. However, contingent experiences of climate change, overutilization that exceeds carrying capacity of natural resources, health problems related to low physical activity or pollution, low quality urban services, diminishing quality of life, inequalities in highly populated urban areas, and so on point out the fact that surpassing solely economic development is not sustainable in the long term, and subordinated dimensions of development, social and environmental, should be embraced with economic counterparts. Economic, social and environmental considerations related to sustainable urban development (SUD) originate from the definition of sustainable development. After the Brundtland definition (World Commission on Environment and Development, 1987), consequent sustainability debates have pointed out that economic interests and environmental considerations are not opposite or conflicting sides of development discourse, and in order to secure intergenerational equity, these sides should meet upon agreed mutual interests.

While SUD encompasses a wide range of urban planning interests, for example, sustainable urban economy, infrastructure and services, integration of communities, green attitudes, public participation, and governance, most of the SUD issues are discussed focussing on spatial considerations, particularly on the urban form and its effects on mobility patterns. Starting with the revelation this interdependence between the urban form and travel pattern of the individuals/households could make it possible to address causes of and intervention options to pressing sustainability problems. These problems consist of urban sprawl, high vehicle kilometres travelled (VKT) and auto dependence, low public transport patronage, transport related pollution, excessive land consumption, disruption of ecosystems, and so on. While rhetorical discussions related to these problems provides a conceptual framework to achieve a comprehensive approach, modelling studies are invaluable sources for identification of causal relationships between urban land use and travel demand.

In addition to the theoretical debates over sustainable development, measurement of sustainability level of an urban setting and use of the findings acquired by various assessment methods to generate integrated and acceptable policy measures embody practical dimension of SUD. Various impact assessment techniques have been mandated by government before the implementation of projects as a prospective evaluation tool. However, due to relatively technical and sophisticated procedures of these methods as well as drawbacks experienced in making social and environmental values tangible, sustainability indicators as a semi-structured and inherently subjective evaluation method have gained wide acceptance and become a standard exercise globally. Besides their use for monitoring and assessment of development strategies, they have provided a common base for public debate on the sustainability subjects and have been employed as a communication tool particularly by various local governments. While visualizing phenomena and highlighting trends (Warhurst, 2003), indicators reflect a scattered illustration of sustainability performance. Because of this, aggregation of indicators, at least categorisation as to the main dimensions, and providing an overall picture via a composite index have recently become another practical approach to sustainability evaluation. Even though composite indices have some methodological drawbacks (for example, different weighting procedures inevitably raise the question of methodological subjectivity, summation of distinct entities as if they have the same unit cause ambiguity about reliability of indices) and practical difficulties are encountered in different settings (generalisation of findings of indexing studies), the number of studies about its reliable application for diverse interests has been growing. Along with the spatial content of urban sustainability, it has become a necessity to include the urban form related indicators in the urban sustainability assessment process. Particularly, developments in GIS technology have facilitated generation and evaluation of spatial indicators. Currently, GIS tools are used for descriptive analysis of urban settings and as a decision support tool. As such, it is possible to effectively exploit capabilities of a GIS platform to develop a sustainability assessment tool as well as a policy formulation and evaluation system.

Our research aims to develop a decision support tool which is used by local government specifically in Australia to generate effective policies towards sustainable urban development. The model presented here with a hypothetical case study employs a spatial indexing method and aggregates theoretically and politically relevant and valid indicators to an index value, reflecting sustainability performance of the urban settings. While it considers local sustainability objectives and policies, it also embraces universally accepted measures of sustainable neighbourhood design and mobility with analytical tools of GIS. The outcome of model, index value, will be used by planning agencies and councils in various ways. To name a few, to analyse of the best localities where overall sustainability level can be enhanced, or at least retained, with the new development, to diagnose of problem areas as to their poor sustainability performance and to generate area specific economic and social policies in solving these problems, and so on. The paper starts by defining sustainable mobility and urban form and explaining indicator and indexing base sustainability assessment techniques. Integrated Land use and Transport Indexing Model (ILTIM) is then explained by giving structural details of the model. The paper is concluded by presenting initial snapshots of a hypothetical example and by discussing the practical use and importance of the model.

Defining sustainable mobility and urban form

The interrelationship between urban form and transportation has been discussed for a long time and it is revealed that, at the operational level, changing lifestyle, attitudes and behaviours are the main drivers of urban form and transport related sustainability problems. In SUD, urban form discussion involves mainly density and mixed land use dimensions, acknowledging the urban sprawl problem. Furthermore, the car dependency and urban sprawl relationship is another popular subject in this respect. (Kenworthy et al., 1996; Banister, 1997; Banister et al., 2000; Low et al., 2003; Todd Litman et al., 2006; Shore, 2006). These studies make descriptive comparisons (i.e. transport and building energy use, VKT, public transport patronage, waste and pollution generated, community integration, and so on) between compact and dispersed city forms, which also corresponds to neo-traditional and suburban style urbanisation discussion, as can be seen in Figure 1. The principal function of urban consolidation via intensification and mixed use is that it reduces trip lengths and total travel, and also changes modal split from automobile dependent to public transportation and non-motorised means (Banister et al., 1997; Cervero et al., 1997; Ewing et al., 2001). Additionally, in terms of social equity and accessibility to urban services, Burton (2000) states that low density urban sprawl imposes economic and social burdens on low income groups towards deterioration of community sense and feeling powerless. It is also asserted that neo-traditional settlement forms satisfying high density and mixed use features are more sustainable than suburban type urban development (Banister et al., 1997; Cervero et al., 1997; Susan Handy et al., 2002). As given in Figure 1, conceptualisation of aforementioned good policies has revealed various urban form approaches, such as Urban Village (Newman et al., 1999), Transit Oriented Development (Boarnet et al., 1997), Smart Growth (American Planning Association, 2002), Decentralised Concentration (Holden, 2004), New Urbanism (Katz et al., 1994), and sustainable urban matrix (Hasic, 2000).

A considerable number of studies have investigated how the externalities of the current surface transport system (non-renewable fuel use and greenhouse gas emissions, traffic congestion, low and unequal mobility, pollution, accidents and fatalities, degradation of ecosystems) may be minimised and/or internalised, while benefits of mobility are maximised and shared equitably through sustainable urban and transport development means (see Figure 1). Therefore, planning and management of transport infrastructure are central foci in the consideration of how the movement of people and goods might be configured according to a sustainable transport framework. In this regard, the efficient use of resources requires particular attention to economic, environmental and social dimensions. In practice, three action domains or elements of any transport activity – vehicle, infrastructure and user – need to be considered in the search for sustainable urban transport solutions (Figueiredo et al., 2001).

Betterment strategies for the first two elements (vehicle and infrastructure) mostly rely on technological improvements in alternative fuels, vehicle systems and surface transport infrastructure. With respect to the third (user) domain, alteration of users' travel behaviour in the interests of sustainability necessitates travel demand management (TDM) policies. The primary function of TDM is to reduce automobile travel demand, and it has become ubiquitous in urban transportation policies in Europe, Canada, Australia, and many areas of the United States. TDM mainly focuses on relationship between urban form and transportation, and socio-economic dimensions, such as household characteristics affecting location choice, daily and holiday travels, mode choice, acceptability of TDM policies, and so on (Ewing et al., 2001; Mindali et al., 2004; Holden, 2007).

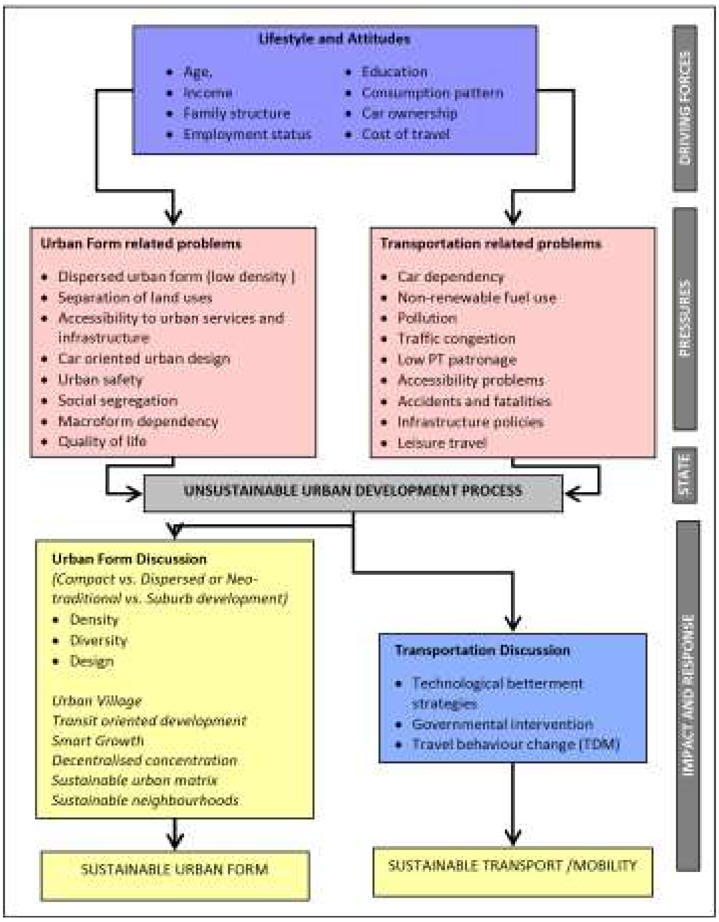

Figure 1. Driving Force-Pressure-State-Impact-Response framework for sustainable urban development

Indicator and index based sustainability assessment

Two considerations demand attention in terms of how selected policies and projects have satisfied or are satisfying designated sustainability goals. The first is the need for a structure, common language or common understanding of sustainable development, on which all stakeholders agree. And the second is to find ways of assessing and measuring process (Brandon, 2002). The following section focuses on the latter issue in more detail.

Background

Due to growing demand from the public towards internalisation of environmental concerns into the governmental policies, starting from the early 1960s, different environmental assessment approaches have started to come to public agenda. Formalisation of environmental assessment methods dates back to late 60s, starting in the United States with The National Environmental Policy Act (NEPA) of 1969. By this act, environmental impact assessment (EIA) was required for land use planning endeavours which were likely to have environmental impacts (Wathern, 1998, pp.3-5). Following this, particularly the industrialised countries started to adapt EIA procedures to different contexts and contents as to their environmental considerations and/or priorities. However, a closer examination of EIA regulations reveals that there has been an agreement on its basic intentions and core elements (Jay et al., 2007). Moreover, cross boundary effects of environmental problems and the need for a new global development strategy, which then conceptualised as sustainability, were revealed at the UN Conference on the Environment in Stockholm in 1972. After the introduction of sustainable development concept by UN World Commission on Environment and Development in 1987 (World Commission on Environment and Development, 1987), the content and core elements of environmental assessment methods have become comprehensive and inherently complex. The critique of EIA due to its limited scope, which is applied generally at project level and this does not suffice broad environmental goals (Shepherd et al., 1996), and changing definition of sustainable development give rise to a search of new assessment methods. Relatively more recently, SEA method has been introduced and become one of the most debated subjects in the literature. Additionally, particularly in the arguments related to corporate level sustainability, triple bottom line approach was introduced by Elkington in 1996.

Indicator based environmental assessment methods also have a long history. The first initiative is dated back to 1929, when national indicators project was initiated by the US President Herbert Hoover, and was administered by Research Committee on Social Trends (Sawicki et al., 1996). Indicators as assessment methodology were founded in the 1960s and improved by the rationalist/system approach of the era. In the 1960s, the indicators were mainly quantitative and based on statistics. By the 1970s, a shift towards health, quality of life and environmental indicators, qualitative factors were beginning to be covered by different studies as shown in Table 1 (Coplak et al., 2003, p.64). By the 1990s, after the improvements in GIS technology, indicator-based sustainability assessment and indexing studies proliferated.

Table 1.History of indicator development

Time frame	Indicator area
1920s–1930s	Social indicators
1940s–1950s	Economic indicators
1960s	Quality-of-life indicators
1970s	Environmental and health information system indicators
1980s	Healthy communities and quality of life indicators
Current	Sustainability indicators

Source: (Innes, 1990; Hodge, 1997; Schlossberg et al., 2003)

Review of the sustainability indicators

There have been various studies proposing different scopes and contents for sustainability indicators parallel to the growing interest on sustainability. Also, depending on the scale of the consideration, it is very common to see international, national, regional and local indicators defined for sustainability. At international level, the United Nations Commission for Sustainable Development and OECD have proposed comprehensive sets of environmental indicators linked with status of and change towards sustainable development. It helps to compare the status of sustainable development on international levels and advises future directions for solutions to global and local problems. Considering the main categories of environment, economy, society and governance, they focus on a number of common concerns, such as, demographic changes, economic development and consumption, climate change and energy, natural resources, sustainable built environment and transport, poverty, public health, social inclusion, security, institutional capacity, and so on.

The main difficulty faced while using indicators is to find a common unit and method of measurement leading to comparison of performance of the setting or policy package. Over the last decade there has been a growing effort towards structuring an international indicator system and monitoring process to make accurate comparisons between countries. In the context of successful methodological and political application of indicators, the European Commission (EC) has defined a set of sustainable development indicators in its framework programmes. Following an evolving process, these indicators now are used by nearly all European countries and provide a benchmarking tool in comparing sustainability performance of each country.

In the context of finding a common unit for measurement, the Ecological Footprint (EF) approach could be considered as a fruitful example. As defined by Wackernagel and Rees (1996) EF documents the extent to which human economies stay within the regenerative capacity of the biosphere. The definition points out consumption or production perspectives related to the activities of nations, cities, or individuals as their role in non-renewable resource depletion. Popularity of this approach comes from its standardised measurement, global hectares, which could be employed when making national, regional, urban and individual comparisons (Wackernagel et al., 2006). Even if it is classified as biophysical accounting models

(Gasparatos et al., 2007), in the assessment of local sustainability level, it is generally used as an indicator.
From regional and local perspectives, sustainability indicators reflect large scale environmental and economic considerations as well as local issues of urban sustainability. In general, the catchments, the habitats of endangered species and natural reserve areas define environmentally sensitive regions, and environmental sustainability considerations are highlighted at the regional scale. In terms of economic activities and urban communities, a divergent range of spatial units from metropolitan areas to small scale infill areas are the main subject of local level sustainability. In these studies there is a growing concern towards balancing environmental, economic and social dimensions of sustainability (Atkisson, 1996). At the local level, status and sustainability of local economy, residential and industrial consumption, recycling, energy security and renewable energy use, local pollution, preservation of ecologically sensitive areas and visual amenities, accessibility to urban services, demographic changes, immigration and integration of social groups, social and gender equity, urban poverty, quality of life and community sense problems, public security, participation level to local decision making process, education and literacy, and public health are the key indicator categories that could be found nearly in all sustainability assessment endeavours. Even if the content and scope of local indicators change from setting to setting, the prime intention is to include locally prominent issues in policy discourse as to their relevance to general sustainability framework and by this, to provide an extensive and inclusive communication platform (Atkisson et al., 2001; Astleithner et al., 2004).
Theoretical and practical qualities of the indicators are the main two domains has been covered in the literature. On the theoretical level, indicators should relate to sustainability and represent different domains of sustainability. On the practical front, they should refer to correct parameters that would be used for policy development and should have enough data background to be used for forecasting. Lautso et al. (2002) define these qualities as relevance (properly embrace the definition and theoretical basis of sustainability), representativeness (cover key issues related to different domains of sustainability), policy sensitiveness (help to formulate policies) and predictability (lead to model policy impacts). It is also emphasised that indicators should be scientifically valid, responsive to the changes in respective system, understandable, and flexible enough to encompass new knowledge and public perceptions (Maclaren, 1996). In relation to data availability and quality, they should be as parsimonious as possible, but they should not suffer from omission of any key indicators. (Hák et al., 2007, p.6). Overall, the main advantage of using indicators is that they can be easily understood by the public and this offers a communication and collaboration means for public involvement in decision making.

Composite indexing approach and its spatial application

Gross Domestic Product (GDP), Gross National Income (GNI), and Consumer Price Index (CPI) are three well-known indices or metrics used to measure economic development and to make comparison between countries and even urban areas, if disaggregated data are available. These indices give overall status of an economy or wealth of a country; however, it is very hard to use them for social or environmental evaluation. To rank countries according to their development level using other than solely economic measures, UN has developed an index, Human Development Index (HDI), which aggregates life expectancy, education and knowledge (literacy and schooling), and GDP by giving equal weights to each item. Although HDI incorporates crucial social attributes with economic metrics to make a clear development definition, it does not comprehend ecological values. There are various studies trying to embody the three domains of sustainability but no one methodology or index which is accepted as sustainability assessment method exists.
The main characteristic of the indices is that in general, they do not have a unit, so that they are considered neutral and comparison between them is viable. Or, they have a unit (i.e. monetary units, ecological footprint, and so on) which make it possible to reflect the index with its original measurement. The procedure followed in the generation of the indices also points out the main weakness of the composite

indicators. Components are assigned weights with the proportion of variances in the original set of indicators, and can then be aggregated using an addition or a functional nature. Weights are used to correct the information overlap of correlated indicators, as to ensure that the results do not display a bias (Hanafizadeh et al., 2009). From another perspective, excluding an indicator or variable from investigation inevitably corresponds to assigning zero weight to respective indicator (Atkisson, 1996). The weighting methodology carries value-dependent biases and, in some cases, weighting with linear aggregation causes substitution among indicators giving rise to acquiring overly-normalised index values (Munda, 2005). Moreover, aggregation of the indicators as an index can cause, in some cases, critical information losses which make it difficult to identify negative or positive changes in the indicator due to the offsetting effects of positive indicators on negative ones (Neuman, 2006).

Spatial indexing has been used by some disciplines for various purposes. Particularly, the widespread use of GIS has led the emergence of many indexing studies in the literature. Among all disciplines using GIS technology, environmental management is the area which spatial indexing with GIS has been most widely applied. Risk assessment of environmental assets (water, forest, and endangered habitats), catastrophes, pollution and suitability analysis for habitat are the subjects in which indexing is employed as the research method. This method has also been used in geography and urban planning by various researches to describe/explore urban issues. Particularly, indexing is used for the analysis and the visualisation of spatial segregation, accessibility to urban services and categorisation of geographic features, such as slope and relative distance to specified point(s).

When it is proved that unit of measurement, normalisation and relative importance (weighting) issues are solved by data analysis tools, indexing is a very resourceful method to visualise and to assess sustainability performance of an urban setting.

Integrated land use and transport model

As a spatial indexing endeavour, the specific aim of this study is to incorporate all related domains affecting urban mobility and propose a practical method that helps the decision making process. At a practice level, there are other dimensions of producing sustainable urban development policies. They are:

- Measuring and assessing the sustainability performance with urban sustainability indicators;
- Aggregation process of indicators to render a composite index;
- Using the composite index to aid policy making.

Initially, in order to clarify key concepts and consolidate the model structure, theoretical debates on definition and measures of the urban sustainability are identified. This procedure gives us a relevant, policy-laden and predictable set of indicators employed by other studies. Then, respective data related to these indicators are collected from various sources, such as, Australian Bureau of Statistics (ABS), Gold Coast City Council (GCCC), and Queensland Transport and Main Roads. Via the indexing module, factors affecting transportation demand is calculated via using factor analysis method. The structure of the model picturing related procedures is given in Figure 2.

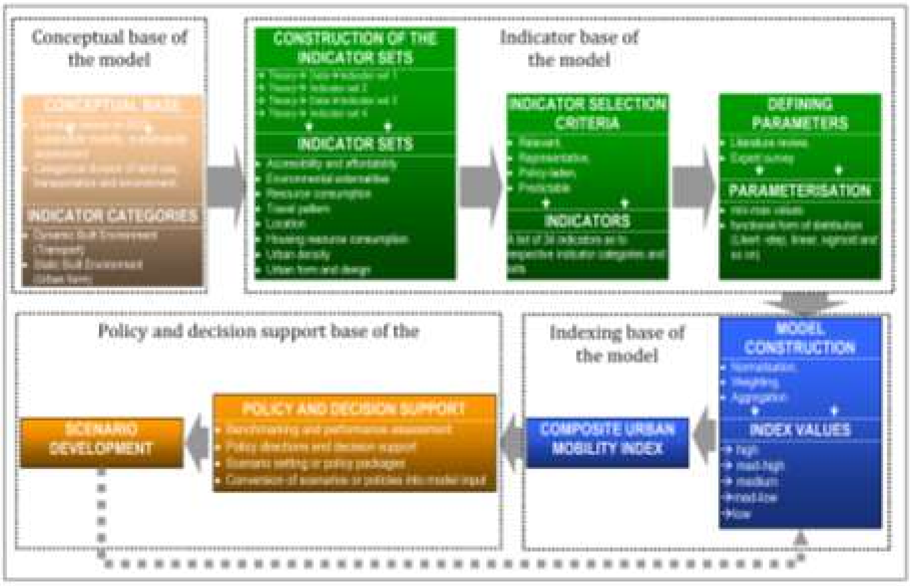

Figure 2. Structure of the indexing model

Conceptual base and data requirements of the model

In order to clarify key concepts and consolidate the model structure, theoretical debates on definition and measures of urban sustainability should be identified. The concept of sustainability and its spatial or urban structure dimension constitute the theoretical foundation of this model. In terms of sustainable urban development and sustainable communities, urban form, mobility pattern and infrastructure provision are the primary issues connected to the environmental domain of sustainability. Even though they are widely used tools, the theory behind the indicator-based description of urban sustainability with scientific reasoning frames the structure of the research and has immense importance for the robustness and reliability of the proposed methods. The review of the literature and the best practice model and cases, the ILTIM Model accommodates two key indicator category areas of dynamic and static built environment. While the former involves mainly transportation infrastructure, specifically externalities of motorised travel and supply of non-motorised and public transport opportunities, the latter focuses on urban form and the resulting socio-demographic pattern of the city.

Construction of the indicator base of the model

In this study, literature of urban sustainability indicators and institutional documents are reviewed and this process gives slightly over 1000, mostly overlapping indicators from different spatial scales (from region to neighbourhood). The main characteristic of the reviewed studies is that they first conceptualise urban sustainability issues, and then suggest compartments varying from general to specific domains. After that they define indicators under these compartments. Furthermore, even if the same wording is used for an indicator, definition and measurement of it may change among these studies. A synthesis of the literature findings has generated two main categories for the indicators. The main categories are employed to structure the indicator system. These two categories are separated into 8 themes and 34 indicators (Cervero et al., 1997; Newton et al., 1998; European Commission, 2001; Black et al., 2002; S. Handy et al., 2005; Christy Mihyeon Jeon et al., 2005; Gold Coast City Council, 2006; T. Litman, 2007; Allen, 2008). In Table 2 aşağıda, the structure and list of indicators are given.

Table 2. Indicators of the model

Category	Theme	Indicator
Dynamic Built Environment	Accessibility and affordability	Access to public transport
		Transit service coverage
		Transit service density
		Public transport performance indicator
		Accessibility for those without a car
		Average portion of household transport expenditures
	Environmental externalities	Greenhouse gases from transport
		Emissions of heavy metals and polyaromatic hydrocarbons
		Exposure to traffic noise
	Resource consumption	Consumption of mineral oil products for transport
		Land area occupied by roadways/transport infrastructure
	Travel pattern	No of trips by car, public transport, walking and cycling
		Average speed by mode and distance
		Off-street parking spaces per employee in CBD
Static Built Environment	Location	Mixed land use ratio
		Housing and jobs proximity
	Resource consumption	Energy use
		Residential water consumption
		Solid waste generation
		Wastewater generation
		Stormwater reused
	Urban density	Average parcel size
		The number of residents per hectare
	Urban form and design	Number of intersections per square km
		Internal street connectivity
		External street connectivity
		Open space availability and accessibility
		Open space connectivity
		Pedestrian network coverage
		Pedestrian accessibilities
		Walkability, pedestrian friendliness
		Bicycle network coverage
		Bike installations (cycle paths and parking)
		Traffic calming

Urban sustainability indexing system of the model

In this study, as the first step the relationship between indicators and urban sustainability will be clarified. For this, the representative variables in accordance to their individual and partially composite contribution to overall urban sustainability performance will be selected via factor analysis. Regarding the respective factors in the model, it would be possible to calculate the effects of main drivers on the dependent indicator.

The second step in the model is to normalise the values of each indicator before weighting and aggregation procedures. There are three widely used methods for normalisations (Singh et al., 2009). The first method is to use standardised distributions, such as the normal or t-distribution. Secondly, it is possible to convert all values into standard ordinal scale, e.g. Likert scale, or thirdly, linear arithmetic normalisation procedures could be employed using minimum and maximum values of the indicators. The main differences between these approaches are that they give different weights to the values as to their difference from the mean value. Or, as in the Likert scale, the values are placed into distribution-free scale bringing researchers' or public perceptions into the normalisation procedure.

The third step involves the weighting of each indicator or factor. Various techniques such as multivariate analysis, factor analysis, public and expert opinion techniques, and so on, are employed for this procedure (Hass et al., 2002; Hák et al., 2007; Singh et al., 2009). The main consideration at this stage is to select robust method that evaluates weights as to their relative importance in the model or alternatively, in the decision making procedure. The latter consideration is the reason of public polls or the Delphi method.

The last step in the model is aggregation of the respective indicators to produce a composite index or set of indices. While simple additive rules are generally employed in the literature, it is possible to define a functional form for aggregation. As stated by Singh (2009) ideally, composite indices should remain relatively simple in terms of their construction and interpretation, and the choice of method employed in weighting and aggregation is ultimately dependent on the nature and scope of the particular study.

Several studies propose different methodologies to create a composite index. To name to few, they are factor analysis, principal component analysis, multiattribute utility analysis, analytical hierarchy process, concordance analysis technique, evidential reasoning, fuzzy logic and so on (Black et al., 2002; Lautso, 2003; Tanadtang et al., 2005; Zietsman et al., 2006; C. M. Jeon, 2007; Rassafi et al., 2007; Hanafizadeh et al., 2009). In this study, the factors extracted at the data reduction step will be used to create a composite index. In order to calculate a single index with individual factor scores, Hanafizadeh (2009) advises the conduct of a linear aggregation with weights derived from the sum of the variance portion of the factor explained by the indicator. It is also possible to weight factors equally or to use the weights advised by the experts. These different weighting options are the subject of sensitivity analysis of the model and are not considered further in here.

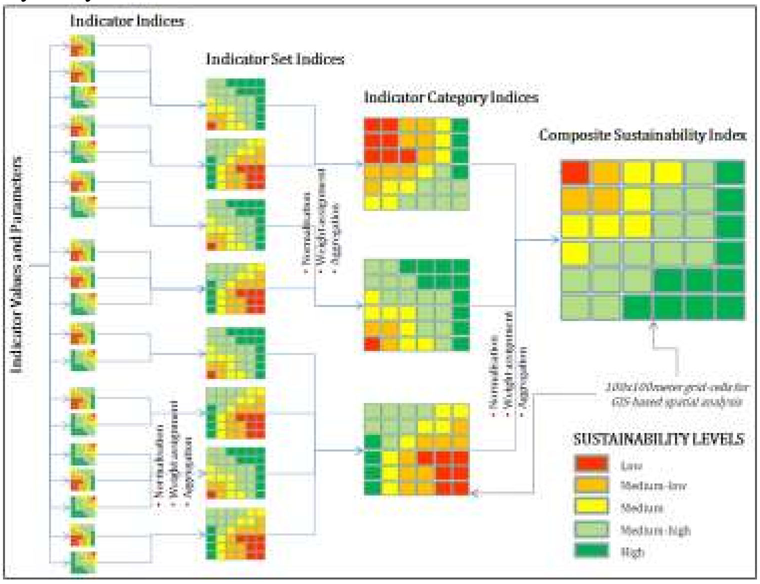

Figure 3. Composite Sustainability Indexing Structure of the ILTIM Model (Yigitcanlar et al., 2010)

For illustrative purposes, the figure above shows how the indicators are aggregated by the proposed spatial indexing model.

Policy and decision support system of the model

The index developed by the model will be used for benchmarking and performance assessment of urban sustainability level, its related policies and strategies, both current and future. This will allow for the review of the capacity and sustainability levels of current urban formation, and enable the forecasting of future scenarios. It will also enable the use of critical indicators for policy direction, strategic formation and as a decision support system. The model will also be used for forecasting; future infrastructure scenarios can be evaluated using predicted data, such as the assessment on infrastructure plans in the South East Queensland Regional Plan and Program 2009-2031 (Queensland Department of Infrastructure and Planning, 2009). This indexing model can be used for informing policy, strategy formation and also as a planning or decision support system. Some of the particular planning policy areas that the ILTIM Model is relevant to include: Planning and managing sustainable urban development; Planning the development of sustainable transport infrastructure and services; Planning for and prioritising sustainable urban infrastructure; Assessing the development applications; Designating conservation areas; Safeguarding existing environmental assets and values; Developing policies for sustainability and intervening with unsustainable development; Increasing awareness among the community via participatory planning mechanisms promoting urban sustainability.

The ILTIM Model has the communicative advantage of being easy to convey comparative levels of sustainability, making it a relatively simple exercise for both the general public and decision makers to understand.

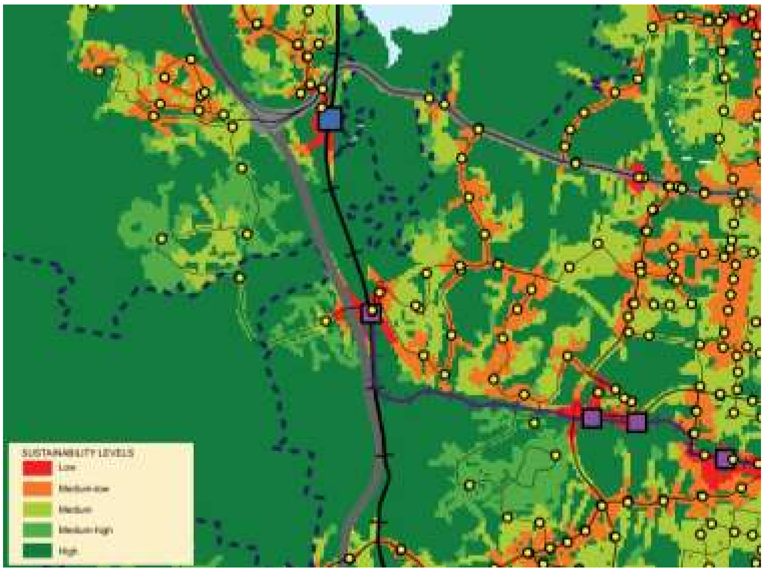

Figure 4. Sample Composite Indexing Map of the ILTIM Model (Yigitcanlar et al., 2010)

As the ILTIM Model is of developed, at this early stage of the project it could only be tested with dummy figures in a case study Gold Coast, Australia. The main purpose of this dummy pilot study is not to measure accurate sustainability levels, but to see whether the model works properly and provides meaningful findings. Figure 4 demonstrates an example of the composite index developed for part of the Gold Coast City by using hypothetical data. Unsurprisingly the application of the model in a hypothetical exercise in the Gold Coast showed that areas around major arterial roads and main activity centres generally have low sustainability levels compared to those close to green spaces and natural environment. This experiment has demonstrated that the model in the broad sense working properly and ready for minor adjustments and calibration.

Conclusion

The research results demonstrate that it is possible to produce a viable local level sustainability assessment model, to apply the model to a major urban area (e.g., Gold Coast City), and to produce a mappable sustainability index. However, this paper only describes the first iteration and in this first run we only looked at the basic two key dimensions of urban sustainability (i.e., urban form and transport). Further research is anticipated, which will focus on enhancing the model by testing various indicators in order to best reflect comparative sustainability levels of urban localities. Decreasing the grid cell sizes and developing a parcel-based module of the model are among the improvements to be explored in future refinements. All these improvements will also be tested in several pilot studies, and several sensitivity analyses with different weightings will be conducted before the final adoption of the model to Gold Coast City Council's planning mechanisms. This example of sustainability indexing and assessment experience with hypothetical data has shown that the model has the potential to help planners and policy makers to embrace an integrated framework for locally adoptable sustainability policies. The model also employs an integrated view of urban dynamics and is not only an invaluable sustainability assessment model, but also a practical planning decision support system. When considered in the context of growing population, urban and environmental problems and climate change, the model has a potential to aid involved parties in forming sustainable urban and transport development policies and in monitoring their impacts on the environment.

Acknowledgement

The paper is a preliminary outcome of an Australian Research Council Linkage Project, ARC-LP0882637: Adaptation of Water Sensitive Urban Design to Climate Change, Changing Transport Patterns and Urban Form. The project is jointly funded by the Commonwealth Government of Australia, Gold Coast City Council, Queensland Transport and Main Roads and Queensland University of Technology.

The authors would like to acknowledge abovementioned project partners and the research team's support.

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