Implications of Land Use Mix on the Sustainability of African Urban Centres: A Case Study of Stellenbosch, South Africa

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1 ABSTRACT

Sustainable development has emerged to guide land use management in most cities yet it is an elusive concept to put into practice. Most African urban centres employ the ubiquitous advocacy-based indicators which dominate sustainability programmes and hinder sound decision making. Moreover, there is paucity in research that investigates land use mix and its impact on urban sustainability in African urban settings. Land use mix is of particular importance given Africa's history of fragmented spatial planning. This paper investigates the use of earth observation data to derive a land use mix index (LUM) and to calculate land use frequency (LUF). It proposes the use of decision consequence analysis as a simple way to put sustainable land use planning into practice and to support day-to-day land use decisions. A model that computes the land use mix and LUF was developed using ArcGIS 10. The results demonstrate that the use of decision consequence analysis, earth observation data, LUM and LUF can aid local planning authorities to go beyond descriptive analysis of urban sustainability to a more robust and objective analysis. Local planning authorities can also use the land use mix index and LUF to effect policy change on sustainability and for day-to-day decision making.

2 INTRODUCTION

Sustainable cities are high on the development agendas of many nations, but are of particular importance in African countries that are experiencing alarmingly high rates of urbanisation (UN-HABITAT, 2009; Shen et al., 2010). Rapid urbanization often leads to land use practices that disregard future needs and cause inevitable problems such as; urban sprawl (Breheny and Batey, 1992), brownfields (Burton, 2000), sedimentation of watersheds (Farrow and Winograd, 2001), urban pollution (Brandes et al., 2010), overcrowding (World Commission on Environment and Development (WCED), 1987), increase of natural and man-made risks (World Bank, 1994), collapse of public services (UN-HABITAT, 2002), soil degradation (Sattler et al., 2010) and haphazard development (Hicken, 2009), often leading to the consumption of natural landscapes needed for urban parks and recreation (Barredo and Demicheli, 2003; UN-HABITAT, 2002).

3 SUSTAINABLE DEVELOPMENT AND LAND USE PLANNING

Sustainable development is a fuzzy concept (Winograd and Farrow, 2007) encapsulated in the seminal definition by the Bruntland Commission as "Development that meets the needs of the present without compromising the ability of future growth to meet their own needs" (WCED 1987, p 23). It follows that for urban land use to be sustainable it has to meet the needs of the current as well as future urban citizens (Seghezzo, 2009; Wolf and Meyer, 2010). Accordingly, cities should be able to sustain the call by today's citizens to alter land use without jeopardising the future generation's needs. Sustainable development and urban land use planning are noble concepts (Hall, 2010), but the challenge is to put them into practice. Ideally, they should be incorporated into a comprehensive decision framework to guide daily, personal, business or policy decisions (Hall, 2010; Ness, 2001). These grand intentions are, however, difficult to monitor and implement given their complexity, vagueness and, at times, immeasurable tenets (Zhang et al., 2011). Sustainability often remains a condition that can be used and abused by various stakeholders without clearly defining what it implies in a land use planning context (Hall, 2010). What is required is a model of sustainable development which accurately captures and allocates costs, such as environmental damage, pollution and land consumption. Decision consequence analysis (DCA) can assist in simplifying the complexities associated with sustainable land use management.

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4 DECISON CONSEQUENCE ANALYSIS

DCA formalises the decision-making process by making use of decision theory, probability and statistics (Hall, 2010). The process breaks down complicated problems, such as sustainable development and land use, into increasingly smaller units until the particular component can be accurately analysed and understood within the context of the overall problem. The basic elements of DCA are an unacceptable current condition and a desired future condition. To achieve a transition between these two it is necessary to have an understanding of each condition, to identify possible pathways between the two and a way to measure the progression between them.The current action trigger in most African cities and towns is the high rate of urbanisation which leads to unsustainable land use practices (Klosterman, 2001). The challenge is how to measure or diagnose progress between the current state and the desired state (objective) of maintaining sustainable land use practices. A proposed solution is the employment of objective metrics developed using geographical information systems (GIS) and data collected with earth observation methods.

5 EARTH OBSERVATION

Campbell (2006) defines remote sensing of the earth's surface (earth observation) as the practice of deriving information about features on the earth's surface using images acquired from an overhead perspective. Earth observation has the capability to provide a quick synoptic view of a city and is consequently extremely valuable for collecting information in developing countries were municipal records are seldom able to keep pace with the rate of development (Hall, 2010; Repetti, Soutter & Musy, 2005). Earth observation also uncovers aspects of the built environment that are often opaque to urban planners and social scientists (Bar and Ford, 2010) and has been used in sustainability studies as a data source for indicator development (National Academy of Sciences, 2003). These indicators include land use/cover (Barredo and Demicheli, 2003), road networks (Victoria Transport Institute, 2010) and building density (Angel, 2010). It is difficult, time-consuming and prohibitively expensive to collect such data by other means (e.g. field surveying) (National Academy of Sciences, 1998).

6 SUSTAINABILITY INDICATORS

Sustainability indicators are bellwether tests of sustainability and they reflect something basic and fundamental about the long-term economic, social, and environmental health of a community (Maclaren, 2004). Such indicators are pointers toward progress or lack of the overall health of a community, neighbourhood, town, city, region or larger area and must reflect the overall well-being of urban land use, should be integrating, forward-looking (Maclaren, 2004), distributional, and subject to feedback loops (Hall, 2010). Examples include (1) land use change (Wang, Cheng and Chen 2011), (2) land use mix (LUM) (Song and Rodriguez, 2005) and (3) land use frequency (LUF) (Guindon and Zhang, 2005). Employing such indicators replaces the ubiquitous advocacy-based approaches which dominate the sustainability programmes in Africa and hinder sound decision making.

Land use change is an important indicator in urban sustainability as it measures the rate of transformation of mostly agricultural and natural ecosystems to intensive urban uses (Wang, Cheng and Chen, 2011). It has been demonstrated that a high rate of land use change due to urban growth leads to increased motorised transport (Victoria Transport Institute, 2010), energy consumption (Urban Land Institute, 2010), loss of agricultural land (Comber, Brunsdon and Green, 2006), loss of biodiversity (Yang et al.; 2009) and increased water pollution (Zhang et al., 2011). Similary, the impact of LUM on urban sustainability has been demonstrated by Song and Rodriguez (2005). The land use mix index is based on the principle of people moving between different activities or different destinations such as home to workplace or shops, and home to civic institutions such as places of worship and parks (Litman, 2010; Polzin, 2006). The LUM index is consequently a measure of variation (Song and Knaap, 2005), dispersion or diversity of land uses (Neat GIS Protocols, 2010). The equation for the LUM index is:

$$= \{-\Sigma_k [(p_i)(ln\, p_i)]\} \,/\, (ln_k)_k$$

Where is the proportion of each land use class per neighbourhood; is the natural logarithm; and is the number of land use classes. Essentially, the LUM measures the extent to which land uses are heterogeneously distributed within a neighbourhood (NEAT GIS Protocols, 2010). The index values range from zero to one where 0 indicates land use homogeneity, which is less sustainable, while a value of 1 represents heterogeneity which is more sustainable (Song and Rodriguez, 2004). The LUM can be global (GLUM) and local (LLUM), where the GLUM is a measure of the overall mix of a city or town while the LLUM shows distributin of the LUM within neighborhods of a city. Ultimately, the land use mix affects sustainability through its impact on environmental, social and economic costs (Figure 1).

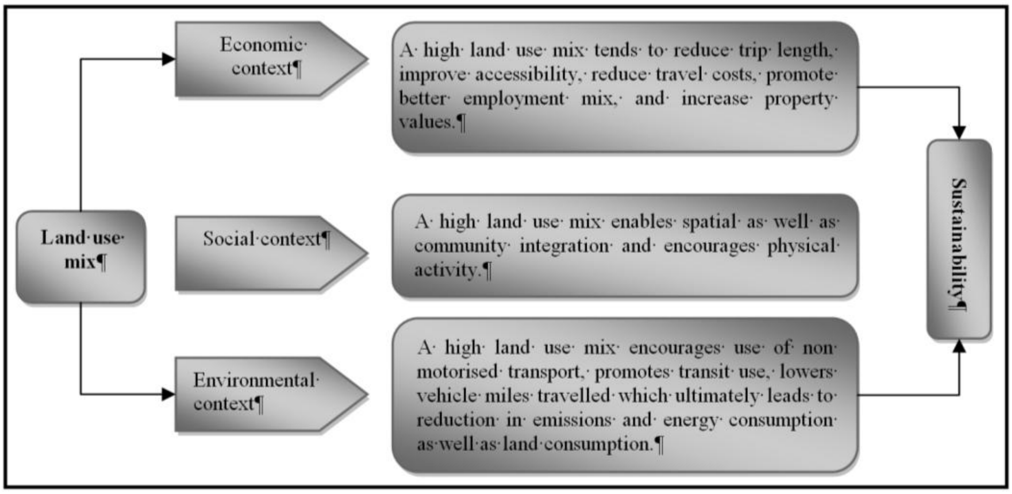

Fig. 1: Impact of land use mix on urban sustainability.

Alternatively, land use frequency refers to the number of land uses found in a neighbourhood or city. It is analogous to having a variety and complimentary of land sues such commercial, residential, education and recreation within a neighbourhood (Song and Rodriguez, 2005). Similar to the land use mix index, land use frequency has perceived social, environmental and economic impacts.

7 METHODS

Study area

Stellenbosch, the second oldest town in South Africa, was chosen as study area. The town is situated in the Western Cape province of South Africa approximately 55 km east of Cape Town's central business district According to Interstudy (2009), Stellenbosch has an estimated population of 60 000 of whom 27 700 are students (Stellenbosch University, 2010). Stellenbosch consists of suburbs of great wealth coexisting with impoverished townships, informal settlements and poor households. Consequently, Stellenbosch faces the challenge of balancing urban and economic growth against expansion into and consumption of valuable agricultural land, and the preservation of natural and cultural heritage while simultaneously attempting to alleviate abject poverty.

Data collection, land use mapping and analysis

Ortho-rectified colour aerial photographs and cadastral data of Stellenbosch where obtained from the Centre for Geographical Analysis (CGA) for 2000 and 2010 respectively. SPOT5 imagery for 2010 was acquired from the South African National Space Agency (SANSA). A land use map of 2000 was obtained from Dennis Moss Partnership. A land cover classification was performed on the 2010 SPOT5 imagery, using a supervised Geographical Object-Based Image Analysis (GEOBIA) approach. The resulting land cover map was visually interpreted along with ancillary data to develop a land use map. Land uses were classified per land parcel in ArcGIS 10 by means of a land use classification rule set which was adapted from Anderson et al.'s (1976) land use classification scheme.The land use maps of 2010 and 2000 were used to calculate GLUM, LLUM and LUF indexes. The latter two indexes were calculated for neighbourhoods 2x2 km in size. This neighbourhood size was selected as they correspond to actual land use development patterns and are sufficiently large for use of none-motorised transport and automobile use (Ewing and Cervero, 2001). All analyses were automated in the model builder tool of ArcGIS 10.

8 RESULTS AND DISCUSION

Land use mix index

The GLUM index for Stellenbosch is relatively high, registering, 0.74 and 0.72 in 2000 and 2010 respectively. The high global land use index value suggests heterogeneity in land use patterns as well a surge toward spatial integration of land uses in Stellenbosch. The high value denotes a high level of social integration and the index functions as a proxy for the vibrancy of the civic life in the town. Given South Africa's spatial policy which is geared toward integrated development, the GLUM index can be used as a measure of spatial as well as social integration.

Unlike the GLUM index, the LLUM index is a breakdown of the global index. Figure 2 shows that some areas in Stellenbosch have higher LLUM index values and that there is a band of relatively low LLUM (less than 0.6) stretching from the south-western (near Technopark) to the eastern parts (in Uniepark) of Stellenbosch. This band of low LLUM suggests a lack of diversity in land use and spatial dispersion of land uses and these have adverse social, environmental and economic costs which hamper sustainable development. In the north-eastern parts of Stellenbosch, spesifically suburbs Welgevonden, Khayamandi, La Colline and Onder Papegaaiberg, the land use mix index rises above 0.6 suggesting diversity of land uses which minimises economic, social and environmental costs.

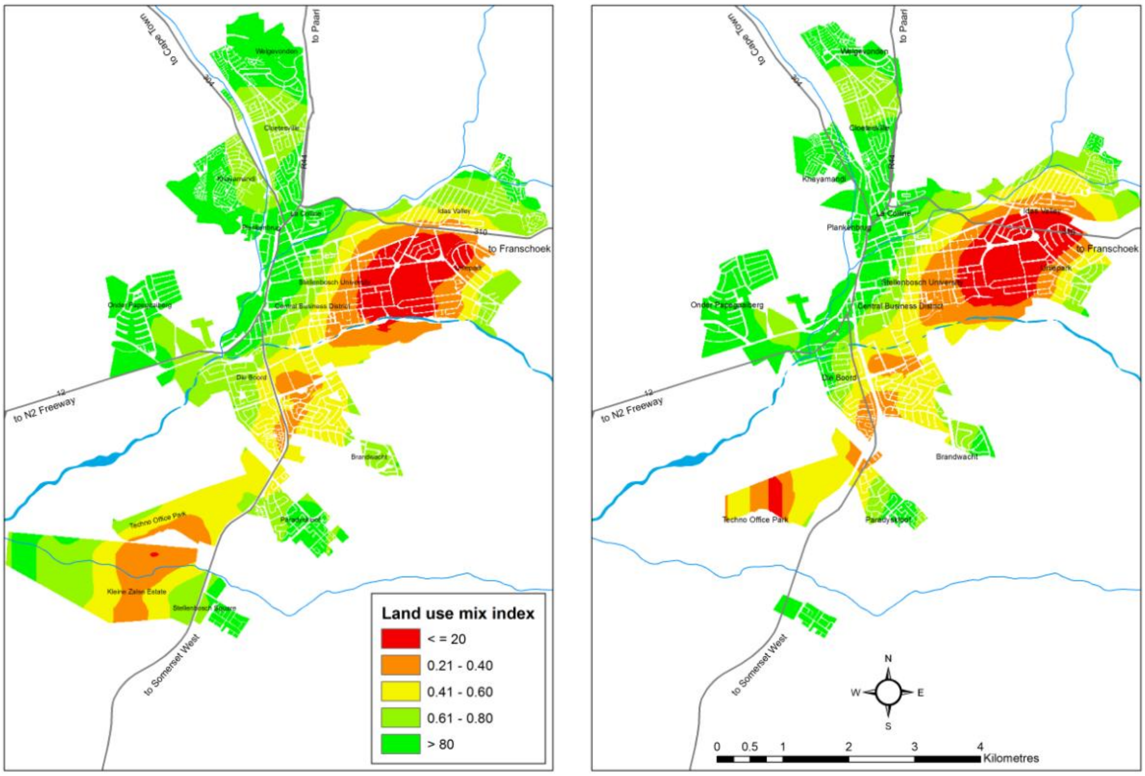

Fig. 2: Distribution of land use mix index values in Stellenbosch, (a) 2000 and (b) 2010.

Over the ten year pereid the change in the LLUM is minimal, however most changes occurs in the urban edges, near Stellenbosch Square in the south and Welgevonden in the North, which could potentialy indicate urban sprawl. Analysis of the change in LLUM can assist planners and decisions makers to implement local planning policies that encourage mixing of activities. Inspection of the LUF per neighbourhood portrays how LUF affects the LLUM.

Land use frequency

The map of LUF for Stellenbosch shows an intensification in the land uses from 2000 to 2010 (Figure 3). There is a band of low LUF per neighbourhood stretching from Technopark, Paradyskloof to the southern parts of Stellenbosch with fewer than nine land use classes per neighbourhood in 2000. This band dimisishes in intensity in 2010 with a general increase in the number of land uses noticable in the southern parts of the town. However, this increase can be partly attributed to the addition of Kleine Zalse Estate and the Stellenbosch Square shopping centre development, which had a positive effect on LLUM in the southern parts of Stellenbosch.

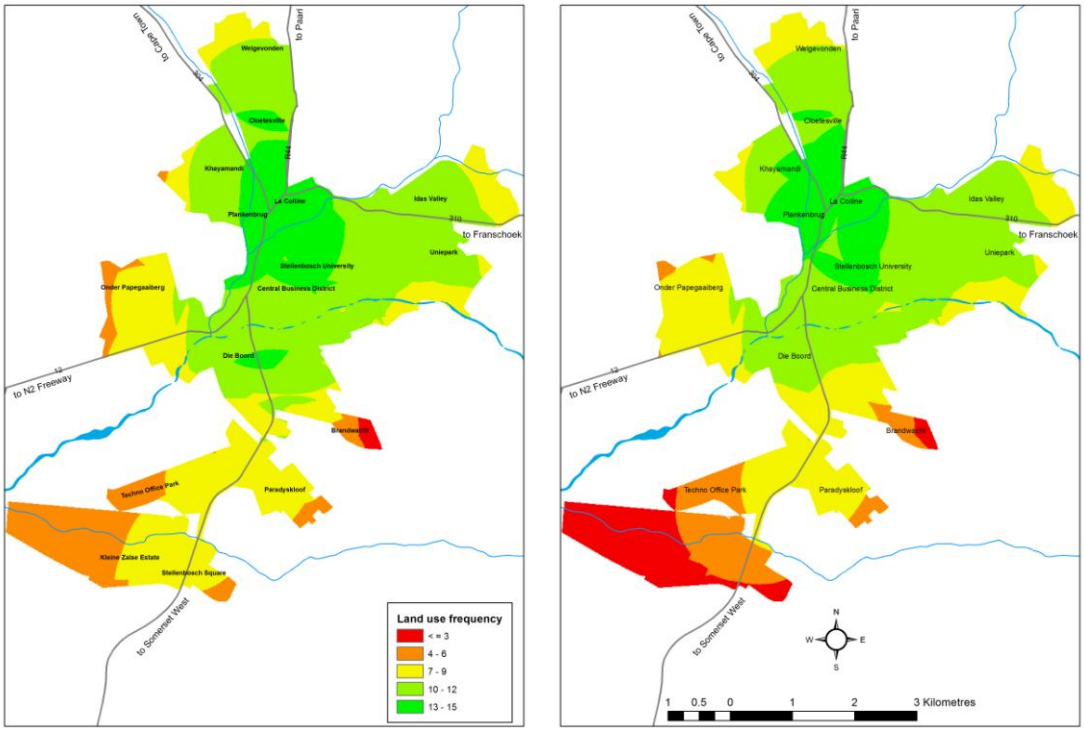

Fig. 3: Land use frequency distribution in Stellenbosch, (a) 2000 and (b) 2010.

Low LUF does not necessarily correspond to a low land use mix. For example, neighbourhoods abutting the Central Business District have a LUF of between 10 - 12 due to land use gentrification as a consequence of the change to greater mixed use comprising commercial and residential uses, yet those central neighbourhoods exhibit LLUM index values of 0.6 or less. In contrast, neighbourhoods abutting Welgevonden in the north experienced an intensification of LUF over ten years accompanied by an increase in the LLUM from 0.3 to 0.8. Similary, the LUM in southern parts of Stellenbosch changed as a result of the new commercial (Stellenbosch Square) and cluster housing (Kleine Zalse Estate) developments where the LUM mostly registers values of 0.6 or less. LUF and the LUM are correlated closely although an increase in the LUF does not necessarily equate to an increase in the LLUM. The LUM and LUF are objective, but they cannot be used in isolation as they cannot indicate areas where urban sprawl is potentially occuring particulary around Stellenbosch square in the south and Welgevonden in the north.

9 CONCLUSION

The study has demonstrated that the LUM and LUF are essential indicators in descring the mix of land uses which is a crucial factor in acheiving urban sustianability. The LUF and LUM allow planners to advance from basic descriptive sustainability reports, which can be subjective and rudimentary, to more robust objective assessments which can be actively applied in decision making. Moreover, these indicators aid in the identification of best practices which can be replicated elsewhere.Though the LUM and LUF are objcetive they fall short in identifying urban sprawl as such they should not be used alone. Both earth observation and DCA make it possible to put the elusive concept of sustainable development into practice to make day-to-day planning decisions or effecting policy changes.

10 REFERENCES

Anderson, J.R., Hardy, E.E., Roach, J.T. AND Witmer, R.E.: A land use and land cover classification for use with remote sensor data. United States Government Printing Office, Washington D.C, 1976.

Barr, S., AND Ford, A.: Integrating urban remote sensing with GIS. In Comparative Genetics Cities Workshop, 22 May 2010, University of California, 2010.

Barredo, J I and Demicheli, L: Urban sustainability in developing countries' megacities: Modelling and predicting future urban growth in Lagos. In: Cities, Vol. 20, Issue 5, pp 297-310.

Bhatta B., Saraswati S. AND Bandyopadhyay D.: Quantifying the degree of freedom, degree of sprawl, and degree -of-goodness of urban growth from remote sensing data. In: Applied Geography, Vol. 30, pp. 96-111, 2010

Brandes, U., MacCleery, R., Peterson, J. AND Johnston, M.: Land use and driving: The role compact development can play in reducing greenhouse gas emissions. Urban Land Institute, Washington DC, 2010
Breheny, P. AND Batey P.W.J (Eds): Sustainable development and urban form (2nd ed). Pion Limited, London, 1992
Burton., E: Measuring urban compactness in UK towns and cities. In: Environmental Planning B: Planning and Design, Vol. 29, pp219-250, 2002.
Calthorpe Associates: The role of land use in reducing VMT and GHG emissions: A critique of TRB special report 298. California, 2010.
Campbell J.B.: Introduction to remote sensing (4th ed.). Guilford Press, New York, 2006.
Canadian Urban Institute: Energy mapping study. Toronto, 2008.
Comber, A., Brunsdon, C. AND Green, E.: Using a GIS-based network analysis to determine urban green space accessibility for different ethnic and religious groups. In: Landscape and Urban Planning, Vol. 86 Issues 1, pp103-114, 2008
Esch, T., Taubenböck, H., Heldens, W., Theil, M., Wrum, M., Geiss, C AND Dech, S (2010) Urban remote sensing-how can earth observation support sustainable development of urban environments? In Proceedings Cities for Everyone. Liveable, Healthy, Prosperous, Real Corp, Vienna.
Ewing, R. AND Cervero, R.:Travel and the Built Environment: A Synthesis, Transportation Research Record, 1780: 87-114, Transportation Research Board, Washington DC, 2001.
Ewing, R. AND Nelson, A.: CO2 reductions attributable to smart growth in California, National Center for Smart Growth Research and Education, University of Maryland, 2008
Farrow, A AND Winograd, W.M.: Landuse modeling at the regional scale: An input into rural sustainability indicators in Central America. In: Agriculture, Ecosystems and Environment Vol. 85, pp249-269, 2001
Frank, L. AND Engelke, P.: The built environment and human activity patterns: Exploring the impacts of urban form on human health. In: Journal of Planning Literature, Vol 16, pp202-218, 2001.
Frank, L.D., Andersen, M.A. AND Schmid, T.I.: Obesity relationships with community design, physical activity and time spent in cars. In: American Journal of Preventative Medicine, Vol 27, pp87-96, 2004
Freeman, C.: Sustainable development from rhetoric to practice? A New Zealand perspective. In: International Planning Studies, Vol 9, pp307-326, 2004.
Guindon, B. AND Zhang, Y: Using satellite remote sensing to survey transport-related urban sustainability: part 1: methodologies for indicator quantification. In: International Journal of Applied Earth Observation 8, pp149-164, 2005
Gunder, M.: Sustainability: Planning savings grace or road to perdition. In: Journal of Planning Education and Research 20, 208-221, 2006.
Hall, O.: Remote sensing in social science research. In: Open Remote Sensing Journal Vol. 3, pp1-16, 2010.
Hall, W.P.: Decision consequence analysis: A paradigm for decision making. In.: Sustainable land development and restoration: Decision consequence analysis. Elsevier, Amsterdam, pp75-85, 2010.
Hess, M.P., Moudon, V.A AND Lodgsdon, M.G.: Measuring land use patterns for transportation research, Transportation Research Record, 1780, Transportation Research Board, Washington DC, 2001.
Hicken, E.: The application of GIS at a local governmental level as a facilitation tool for sustainable development in rural Africa. Master's Thesis. Kingston University, London, 2009.
Holden, M.: The tough minded and the tender minded: A pragmatic turn for sustainable development planning and policy. In: Planning Theory and Practice, Vol. 9, pp475-496, 2008.
Huang, A., Wong, J AND Chen, T.C.: A framework of indicator system for measuring Taipei's urban sustainability. In: Landscape and Urban Planning, Vol. 42, pp15-27, 1998.
Interstudy.: Stellenbosch University. Retrieved 11/11, 2011, from http://www.interstudy.org/u/23-stellenbosch-university, 2009
Jabereen, R.Y.: Sustainable urban forms; their typologies, models and concepts. In: Journal of Planning Education and Research, Vol. 26, pp38-52, 2006.
Jacques, P.J, Dunlap, R.E AND Freeman, M.: The organization of denial: Conservative think tanks and environmental scepticism. In: Environmental Politics, Vol. 17, pp345-389, 2008.
Jones, C AND MacDonald, C.: Sustainable urban form and real estate markets, Herriot -Watt University, Edinburg, 2004.
Klosterman, R.E.: The appropriateness of geographic information systems for regional planning in the developing world. In: Computers, Environment and Urban Systems, Vol. 19, pp1-13, 1995.
Klosterman, R.E.: Urban planning: Methods and technologies. In Smelser, N J and Baltes, P B (Eds), International encyclopaedia of the social & behavioural sciences. Pergamon, Oxford, pp16055-16058, 2001.
Litman, T.: Land use impacts on transport: How land use factors affect travel behaviour, Victoria Transport Policy Institute, Vancouver, 2010.
Liu, Y.: Modelling urban development with geographical information systems and cellular automata, CRC Press, Boca Raton, 2009.
Lo, C.P AND Faber, B.J.: Integration of landsat thematic mapper and census data for quality of life assessment. In: Remote Sensing of the Environment 60, pp143-157, 1997.
Lynch, K.A.: The image of the city, MIT press, Cambridge, 1960.
Maclaren, V.W.: Urban sustainability reporting. In Wheeler, S M and Beatley, T (Eds), The sustainable urban development reader. Routledge, New York, pp2003-2010, 2004.
Miller, R.B AND Small, C.: Cities from space: Potential applications of remote sensing in urban environmental research and policy. In: European Planning Studies, Vol. 6, pp129-137, 2003.
NASA.:Urban and land use applications: From Los Angeles to Paris. Retrieved 08/06, 2010, from http://rst.gsfc.nasa.gov/Sect4/Sect4_1.html, 2009
National Academy of Sciences: People and Pixels: linking remote sensing and social science, National Academy of Sciences, Washington DC, 2008.
National Academy of Sciences: Using remote sensing in state and local government: Information for management and decision making, National Academy of Science, Washington D.C., 2003
National Research Council: Driving and the built environment: The effects of compact development on motorised travel, energy use and CO2 emissions, National Academy of Science, Washington D.C., 2009

NEAT GIS Protocols: Neighbourhood environment for active transport-geographic information systems. Forsyth, A (Ed). Design for health.net, Cornell University, 2010.
Nijkamp, P., Lasschuit, P AND Soetmaan, F: Sustainable development in a regional system. In Breheny, P and Batey, P W J (Eds), Sustainable development and urban form. Pion, London, pp39-66, 1992.
Opschoor, H AND Reijnders L: Towards sustainable development indicators. In Kuik, O and Verbruggen, H (Eds), In search of indicators for sustainable development. Kluwer Academic, Dordrecht, pp 7-27, 1991.
Ness, P: Urban planning and sustainable development. In: European Planning Studies, Vol. 9, 503-525, 2001.
Phua, M.H AND Minowa, M: A GIS-based multi-criteria decision making approach to forest conservation planning at a landscape scale: A case study in the Kinabalu Area, Sabah, Malaysia. In: Landscape and Urban Planning, Vol. 71, pp 207-222, 2005.
Polzin, S.E: The case for moderate growth in vehicle miles of travel: A critical juncture in U.S. travel behaviour trends. US department of transportation, Washington DC, 2006.
Renetzeder, C., Schindler, S., Prinz M.A., Mucher, C.A AND Wrbka, T: Can we measure ecological sustainability? Landscape pattern as an indicator for naturalness and land use intensity at regional, national and European level. In: Ecological Indicators, Vol. 10, pp 39-48, 2010.
Repetti, A., Soutter, M AND Musy, A: Introducing SMURF: A software system for monitoring urban functionalities. In: Computers, Environment and Urban Systems 30, 687-707, 2005.
Sattler, C., Nagel, U.J., Werner, A AND Zander, P: Integrated assessment of agricultural production practices to enhance sustainable development in agricultural landscapes. In: Ecological Indicators, Vol. 10, pp 49-61, 2010.
Shen, Y., Ochoa, J.J., Shah, M.N AND Zhang, X.L: The application of urban sustainability indicators-a comparison between various practices. In: Habitat International, Vol. 35, pp 17-29, 2010.
Seghezzo, L: The five dimensions of sustainability. In: Environmental Politics, Vol. 18, issue 4, pp 539-556, 2009.
Schneider, A., Friedl, M.A., AND Potere, D: Mapping global urban areas using MODIS 500-m data: New methods and datasets based on 'urban ecoregions'. In: Remote Sensing of Environment, Vol. 114, issue 8, pp 1733-1746, 2010.
Song, Y AND Knaap, G.J: Measuring urban form. In: Journal of the American Planning Association, Vol. 70, pp 210-225, 2005.
Song, Y AND Rodriguez, D.A: The measurement of the level of mixed land uses: A synthetic approach, Carolina Transportation Program, Carolina, 2005.
Spiekermannn, K AND Wegener, M: Modelling urban sustainability. In: International Journal of Urban Sciences, Vol. 7, pp 47-64, 2003.
Stellenbosch Municipality: Stellenbosch municipality integrated development plan, Stellenbosch Municipality, Stellenbosch, 2011.
Stellenbosch University: Fast fact statistics 2010, Stellenbosch University, Stellenbosch, 2010.
Tsai Yu-Hsin: Quantifying urban form: Compactness versus sprawl. In: Urban Studies, Vol. 42, pp 141-161, 2005.
UN-HABITAT: Sustainable urbanisation: Achieving Agenda 21, UN-HABITAT, Nairobi, 2002.
United Nations Center for Human Settlements: Habitat partner university network. Retrieved 07/07, 2010, from http://www.unhabitat.org/content.asp?typeid=19&catid=570&cid=6002, 2009
United Nations Environmental Program: Making the economic case for greening cities. Retrieved 12/11, 2011, from http://www.unep.org/newscentre/default.aspx?DocumentID=2656&ArticleID=8895, 2011
Urban Land Institute: Land use and driving: The role compact development can play in reducing greenhouse gas emissions, Urban Land Institute, Washington DC, 2010.
Victoria Transport Policy Institute: Land use impacts on transport: How land use factors affect travel behaviour. Retrieved 08/09, 2011, from www.vtpi.org/landtravel.pdf, 2010a
Victoria Transport Policy Institute: Land use impacts on transport: How land use patterns affect travel behaviour. Retrieved 04/06, 2011, from www.vtpi.org/landtravel.pdf, 2010b.
Western Cape Department of Environmental Affairs and Development Planning: Western Cape provincial spatial development framework.Retrieved,04/16,2010,from http://www.capegateway.gov.za/other/2009/9/settlement_restructuring_explanatory_manual_mar_09_final.pdf, 2009.
Wheeler, S.M: Planning for metropolitan sustainability. In: Journal of Planning Education and Research, Vol. 20, pp 133-145, 2000.
Winograd, M AND Farrow, A: Sustainable development indicators for decision making: Concepts, definition and use. Retrieved 10/10, 2010, from http://www.eolss.net/ebooks/Sample%20Chapters/C13/E1-46B-02.pdf, 2007 .
Wolf, T AND Meyer, B.C: Suburban scenario development based on multiple landscape assessments. In: Ecological Indicators, Vol. 10, pp 74-86, 2010.
World Bank: Making development sustainable, World Bank, Washington DC, 1994.
World Commission on Environment and Development: Our common future, Oxford, 1987.
Yang, J., Zhao, L., McBride, J AND Gong, P: Can you see green? Assessing the visibility of urban forests in cities. In: Landscape and Urban Planning, Vol. 91, issue 2, 97-104, 2009.
Zhang, X., Wu, Y AND Shen, L: An evaluation framework for the sustainability of urban land use: A study of capital cities and municipalities in china. In: Habitat International, Vol. 35, pp 141-149, 2011.