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Development of a multi-criteria spatial planning support system for growth potential modelling in the Western Cape, South Africa

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ABSTRACT

Growth potential modelling is useful as it provides insight into which settlements in a region are likely to experience growth and which areas are likely to decline. However, growth potential modelling is an ill-structured problem as there is no universally-agreed set of criteria (parameters) that can be combined in a particular way (rules) to provide a definitive growth potential measure (solution). In this paper we address the ill-structured problem of growth potential modelling by combining multi-criteria decision making (MCDM), geographical information systems (GIS) and planning support systems (PPS) to generate a number of growth scenarios for settlements in Western Cape province of South Africa. A new framework and methodology for selecting, structuring and analysing multiple growth potential criteria is proposed. The framework, based on the principles of innovation potential and growth preconditions, was applied to demonstrate how it can be used to identify a series of candidate criteria relating to the growth potential of settlements. The criteria were subjected to a MCDM process involving criteria selection, weighting and normalisation. Two criteria sets, weighting schemes and normalisation methods were considered. Two different classification techniques were also evaluated. A total of 16 scenarios were generated using a newly-developed growth potential PPS (GPPSS). The paper shows how the GPPSS can be used to quantitatively and qualitatively assess the various scenarios and to select the most appropriate solution.

1. Introduction

The importance of space and place in effective development policy is reinforced by the renewed focus on regional development (Ascani et al., 2012). Continued systematic research on the role and function of urban settlements within the developmental context of a region is required to provide a sound foundation to support well-founded strategic decisions (Pike et al., 2010). Of particular interest, especially in developing countries, is the identification of regions or settlements that are most likely to experience sustained growth and where investment and interventions such as land use changes and infrastructure projects will have the greatest socio-economic impact (Henderson and Wang, 2007). Although many settlements have solid developmental bases and are experiencing dynamic growth, some are experiencing reduced economic activities, poor service delivery and deteriorating infrastructure (Bowns, 2013). Decreasing social and economic service levels within settlements invariably impacts negatively on the quality of urban and rural life as the surrounding hinterland is usually also affected. Strategic decisions to promote particular types of development in specific areas require accurate and timely information.

Empirical analyses, such as the application of growth equations and regression modelling, are often used for estimating the growth potential of regions (Arbia et al., 2010; Barro, 1991; Battisti and Vaio, 2008). However, appropriate data for such models is often not available at the appropriate spatial or temporal resolutions. For

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instance, economic measures such as growth value added (GVA) are often only available at regional (e.g. provincial or district) level and are as such not applicable at settlement level. While population figures are usually available at the suitable spatial scale (e.g. ward level), they are in many countries only updated once every ten years. Trends based on data collected at such long intervals are often unreliable, particularly in developing countries experiencing high levels of population growth and urbanization. Empirical models based on the physical growth of settlements are also not pertinent as many settlements have policies in place that restrict urban expansion and encourage densification (Musakwa and Van Niekerk, 2013).

An alternative approach to empirical modelling is to make use of a range of growth-related factors and to analyse them in a deterministic manner. For instance, Zietsman et al. (2006) showed how a range of spatial indicators and indexes can be structured into a framework to model the growth potential of settlements and to guide spatial development policy. However, identifying suitable indicators of growth potential is challenging due to the many factors that may affect a region or settlement's capacity to develop. Another problem relating to a deterministic approach to growth potential modelling is that indicator selection is often subjective or guided by data availability rather than its true suitability. This often leads to the selection of indicators that are strongly correlated, which can lead to compensability problems. In addition, some factors contributing to growth potential may be difficult to map or quantify. For instance, entrepreneurial innovation often stimulates economic activities and social development but is extremely difficult to predict.

The use of empirical and deterministic modelling of growth potential is conceptually flawed as growth potential modelling is not a well-structured problem (Saaty, 1978). Well-structured problems (e.g. mathematics-related problems) have single, correct and convergent answers, while ill-structured problems do not have a finite number of concepts, rules, and solutions (Hong, 1998). Ill-structured problems, also referred to as unstructured or semi-structured (Ascough et al., 2001; Densham, 1991; Goodchild and Densham, 1990), cannot be solved with an algorithm or a predefined sequence of operations. For instance, there is no universally-agreed set of criteria (parameters) that can be combined in a particular way (rules) to provide a definitive growth potential measure (solution). Ill-structured problems may have multiple solutions, solution paths, and criteria (Kitchener and King, 1981). According to Voss and Post (1988), ill-structured problems can be solved by (a) representing the problem, (b) stating the solution and (c) evaluating the results. The representation of the problem consists of stating the nature of the problem and collecting all appropriate information. During the solution stage of the problem-solving process, various solutions or scenarios are generated and selected for evaluation. Evaluation often involves a process of assessing the solution construction and finding consensual agreement among a community about the most viable, most defensible and preferred solution.

Computer systems are often used to support the process of finding solutions for ill-structured problems. Decision support systems (DSS), for example, are computer systems that were specifically designed to solve such problems. Planning support systems (PSS) can be regarded as a subset of DSS aimed at bringing together the functionalities of geographical information systems (GIS), models, and visualization (DeMers, 2009). The purpose of these assemblages is normally to gather, structure, analyse, and communicate information in planning. PSS are often loosely coupled assemblages of techniques to assist planners, technicians and other role players involved in the planning process (Tanguay et al., 2010). Although there are some overlap between GIS, spatial decision support systems (SDSS) and PSS, the latter can be differentiated based on its aim that is purely focussed on planning support. Although SDSS and GIS technologies can normally also be used for planning support if required, they are not solely dedicated to that use (Vonk et al., 2007). The concept of PSS have evolved substantially since the early urban models of the 1960s and 1970s that failed to meet the expectations of users (Batty, 1979) and the introduction of arguments in the late 80's for thinking beyond GIS. PSS now include a wide range of approaches such as rule-based accounting (e.g. What if?), cellular automata (e.g. SLEUTH), and microsimulation (e.g. UrbanSim) models (Kaza, 2010). One of the six important information-handling functions of a PSS is information analysis aimed at generating new information from existing data (e.g. the use of multicriteria analysis systems) which is of particular relevance to this research (Vonk et al., 2007).

PSS normally incorporate predictive analysis to present decision makers with different scenarios to explore the possible effects of their decisions. This type of interactive exploration enables a decision maker to develop a better understanding of an ill-structured problem. PSS normally consist of a database management system, analytical modelling capabilities, analysis procedures, and a user interface with display and report generators. GIS are often used in combination with PSS to find solutions for geographical or spatial problems (Agrell et al., 2004). With the capabilities of GIS to store, manipulate, analyse and present spatial data, Spatial PSS are powerful tools for supporting complex spatial decisions (Ascough et al., 2001).

Although numerous methods exist whereby GIS and PSS can be used to analyse multiple factors and to combine them into a model (Chang, 2006), the multi-criteria decision making (MCDM) approach is one of the most popular due to its ability to divide complex problems into smaller understandable parts that are then evaluated independently. The results of the individual evaluations are integrated to provide an overall solution to the original problem (Malczewski, 1999). By using MCDM, solutions can be found to decision making problems with multiple alternatives, evaluated by decision criteria (Jankowiski and Nyerges, 2001).

This paper adopts the approach suggested by Voss and Post (1988) for solving ill-structured problems by combining MCDM, GIS and PSS to generate a number of growth scenarios for settlements in the Western Cape province of South Africa. A framework and methodology for selecting, structuring and analysing multiple growth potential criteria is proposed. The framework, based on the principles of innovation potential and growth preconditions, is applied to demonstrate how it can be used to identify a series of candidate criteria relating to the growth potential of settlements. Scenarios are generated using a newly-developed growth potential PSS (GPPSS). The various scenarios are then quantitatively and qualitatively evaluated to select the most appropriate solution.

The next section provides an overview of the study area and the methods that were used to model growth potential at settlement level. Although the focus of the paper is mainly on methodological considerations, a short discussion of the analysis results and its value for regional and local decision support is also provided. The paper concludes with comments on remaining challenges and how the modelling methodology can be improved.

2. Methods

2.1. Study area

Donaldson et al. (2012b) evaluated the development potential of 24 non-metropolitan local municipalities in the Western Cape, South Africa by employing a range of spatial indicators collected at municipal level. The resulting indexes and classifications were analysed and interpreted to formulate a set of generic interventions