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Measurement and evaluation of sustainable development A composite indicator for the islands of the North Aegean region, Greece

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ABSTRACT

This paper develops a methodology to analyse, measure and evaluate sustainable development (SD). A holistic approach (systems analysis) is applied to operationalise the SD concept and an integrated approach (composite indicator construction) is adopted for the measurement of SD. The operationalisation of the SD concept is based on an in-depth systems analysis of issues associated with economic, social and environmental problems in a policy context. The composite indicator (overall sustainability index) is developed based on the three composite sub-indicators of the SD dimensions. The valuation of the SD is based both on the aggregated sub-indicators and the overall composite indicator. The methodology is used to evaluate the SD of the North Aegean islands between different temporal points. The assessment of the change in the islands' SD is based on a quartile grading scale of the overall SD composite scores.

1. Introduction

The concept of sustainable development (SD) has brought together many disciplines and interests. Although in theory this proposition can certainly be supported, the same is not true in terms of practicalities. SD is a most controversial notion with respect to its operationalisation. Different ways of measurement have been proposed regarding the monitoring and evaluation of an area's progress towards SD, based on differentiated spatial, temporal or theoretical concerns (Hodge, 1997). Whatever the focus of the analysis (local or global, short or long term, weak or strong sustainability), complex and dynamic phenomena will always be involved in the SD decision making process.

To measure and evaluate SD, complex tools are needed to highlight problems and to assess performances and changes. Much of the work on SD decision making has focused on developing indicators that provide measures of progress towards achieving SD (e.g. Crabtree and Bayfield, 1998; Hanley et al., 1999; Atkisson and Hatcher, 2001; Weng and Yang, 2003; Shi et al., 2004; Lee and Huang, 2007). Indicators have been used for many years as tools to inform policy makers and help formulate developmental policies. Decision making, in the context of sustainability, has focused on composite indicators (CI) to support policy formulation because aggregated indicators are valued as communication and political tools (Freudenberg, 2003).

Despite the interest in the development of sustainability indicators, there are few studies that compare the SD of a specific area for different time periods. In the literature, there are a few attempts that examine how SD conditions change through time (Weng and Yang, 2003; Shi et al., 2004; Lee and Huang, 2007). This paper examines the issue of how conditions change over time through the construction and comparison of a composite SD indicator based on data from two different temporal points (years) a decade apart.

Systems analysis is used to analyse the regional system in focus and to identify and establish the parameters of the created model. The integration of the multidimensional character of the SD concept is achieved by elaborating a composite indicator model. Three sub-indicators are developed that are further aggregated into one composite index for each SD dimension. The latter is used to address the long-term changes in the SD by comparing the values of the CI between two different years (1991 and 2001). The method is applied to the N. Aegean region, an ecologically and economically fragile insular area in Greece.

The structure of the paper is as follows: Section 2 addresses the issues associated with the concept of SD. Section 3 introduces the concept of CIs and presents the steps which are followed in the construction of such indicators. In section 4 the SD concept is operationalised (issues pertaining to each SD dimension are analysed and indicators are selected) by utilising systems analysis and then a CI is used to measure the SD of the case study area. Section 5 assesses the overall sustainability of the case study area, as well as each SD dimension. Section 6 concludes with a discussion of the results, including their implications for policy.

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2. Sustainable development

The concept of sustainable development (SD) and the meaning attributed to it today emerged over the last decades as a result of a growing concern for the environment and its natural resources (cf. Mebratu, 1998; Jamieson, 1998). Although SD is nowadays a widely accepted concept, there still exist issues that need to be addressed at the operational level, such as the appropriate geographical scale for action and the development of effective tools that will help achieve sustainability (Chan and Huang, 2004).

Regarding spatial scale, interest has moved away from the global level towards empirical policy-relevant research at the local level. Concerning in-depth understanding of the SD concept, it is supported that a comprehensive framework is necessary to understand the complexity of interactions in human and natural systems (Nijkamp and Vreeker, 2000). The challenge to understand and manage complex systems emerges from the need to make the decision making process and the implementation of successful policies easier. In this view, systems thinking and integrated approaches are useful tools for planning effective policy interventions, i.e. policies that will assist areas to follow a sustainable path of development.

A system's approach is well-suited to identify decisive information to support SD. Information plays a critical role in SD because it supports the identification of objectives and the development and the evaluation of policies. Moreover, the principles of SD call for an integration of information related to economic, environmental and social factors in decision making (Kelly, 1998).

The identification of decisive information and its effective integration to support decision making, require the development of appropriate frameworks to support these processes. The use of frameworks is essential as they suggest logical groupings of related sets of information and thus, they promote interpretation and integration. In such frameworks, sustainability indicators have been used as appropriate tools in supporting policy implementation (used to measure, monitor and report on the progress towards sustainability), as they allow a better organisation, synthesis and use of information (Walmsley, 2002).

In consequence, using SD as a planning tool necessitates the identification of indicators that will assist policy-makers to identify appropriate policies and to monitor the effectiveness of the interventions. Indicators (individual or highly aggregated indices) provide information on complex phenomena and permit comparisons over time and space. Therefore, the selection of valid indicators is an imperative of rational decision making. Reliance on inappropriate indicators will most likely lead to a continuation or development of inappropriate policies or development decisions (Kelly, 1998).

Therefore, SD as a multidisciplinary concept requires the adoption of integrative and systemic frameworks for measurement and evaluation to be effective and meaningful at the policy level. In addition, a selection of indicators that accurately represent the system is required to measure progress towards SD. Otherwise, it is likely that ineffective policies will be implemented, thereby failing to provide solutions to sustainability problems.

3. Composite indicators

A composite indicator (CI) is an aggregation of indicators or sub-indicators that have no common unit of measurement and no obvious way to assign weights to them. Every CI can be considered a model, and as such it is created for a specific purpose and its construction has to follow a series of steps to be useful and generally accepted. These steps include the following (Saisana and Tarantola, 2002; Jacobs et al., 2004; OECD, 2005):

1) Formulation of a theoretical framework: to be able to provide a sound basis for the selection and the combination of single indicators into a meaningful CI, the theoretical framework must accurately define the phenomena to be measured and the elements that shape them.
2) Data selection: the indicators used should be selected based on their analytical soundness, measurability, spatial coverage, relevance to the phenomenon being measured and their relationship to each other. The use of proxy variables should be considered when data are scarce.
3) Multivariate analysis: this encompasses a wide variety of methods, which can be distinguished into two main categories: exploratory and confirmatory analyses. In the first case, the overall structure of the indicators is examined, data suitability is assessed and methodological choices are explained. In the latter case, the purpose is not to describe but to examine specific assumptions based upon already developed theoretical frameworks.
4) Imputation of missing data: three methods are available for cases with missing data: a) omission of cases with missing data, b) single imputation (e.g. replacement with the mean or median, regression) and c) multiple imputation (e.g. Monte Carlo algorithm).
5) Data normalisation: indicators should be normalised to be rendered comparable. A variety of normalisation techniques is available for that purpose (for a review see OECD, 2005).
6) Weighting: weights greatly influence the output of the composite indicator. Hence, indicators should be weighted either according to an underlying theoretical framework or based on empirical analyses, but also taking into account expert and/or public opinion. In general, there are three ways to assign weights: a) to use statistical models, b) to adopt participatory methods and c) to assign equal weights to the indicators.
7) Aggregation: the aggregation of the indicators can be linear, geometric or can be based on a multi-criteria analysis. In both linear and geometric aggregations, weights express trade-offs between indicators, while multi-criteria analysis assures non-compensability by finding a compromise between two or more legitimate goals.
8) Robustness analysis: a CI is the result of a number of choices made regarding the indicators, the normalisation method, the weighting scheme etc. As a result, the output of a CI depends greatly upon the technique used in each step of the CI creation process. Therefore, it is important to determine whether the values of each CI are affected by the uncertainty that might characterise the data and/or the weights.

Combining uncertainty and sensitivity analysis can help assess the robustness of a CI. Uncertainty analysis focuses on how the uncertainty in the input factors affects the CI values. Sensitivity analysis assesses the contribution of each individual source of uncertainty to the output variance. Ideally, all possible sources of uncertainty must be taken into consideration: a) inclusion and exclusion of indicators, b) modelling data error based on the available information on variance estimation, c) alternative ways to impute missing data, d) different methods of data standardisation, e) Alternative ways to assign weights, f) different methods of aggregation and g) assigning different weights.

The construction of confidence intervals around the CI can be very useful as they help to distinguish differences in performance arising from sampling error and natural variation and those (true differences) for which people are responsible. Wide confidence intervals denote a great imprecision around the estimates. If the confidence intervals overlap to a great degree (indicating a similar performance), then caution is needed as differences in ranking may be a result of the uncertainty of the data.

9) Analysis of the CIs structure: CIs can help the decision making process. However, as they are summary indicators, a decomposition to their individual parts may result in a better understanding of performance and therefore may positively contribute to the decision making process. A variety of techniques is available for presenting such decompositions.
10) Presentation and dissemination of results: a CI must be able to provide an accurate picture to decision makers and any interested