Ecological Indicators 78 (2017) 108–114

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Short Communication

Evaluations of corporate sustainability indicators based on fuzzy similarity graphs

Marie Pavláková Dočekalová*, Karel Doubravský, Mirko Dohnal, Alena Kocmanová

Faculty of Business and Management, Brno University of Technology, Kolejní 2906/4, 612 00 Brno, Czech Republic

ARTICLE INFO

Article history:
Received 11 July 2016
Received in revised form 30 January 2017
Accepted 24 February 2017
Available online 19 March 2017

Keywords:
Corporate sustainability
Fuzzy
Indicators
Similarity graph

ABSTRACT

The paper deals with inconsistencies of composite sustainability indicators and their different subsets (economic, environmental, social, and corporate governance). Corporate sustainability performance is usually highly nonlinear, vague, partially inconsistent and multidimensional. The resulting models are often oversimplified. The key reason is an information shortage which eliminates the unsophisticated applications of classical statistical methods. Numbers are accurate and information intensive. Verbal quantifications are less accurate and therefore not that information intensive. Fuzzy sets and fuzzy reasoning are used to make verbal quantifiers suitable for computer applications. A fuzzy similarity graph is defined. A team of experts identified 17 relevant variables (e.g. Environmental costs, Occupational diseases, Number of complaints received from stakeholders) and 12 company data sets are available. Each company is presented as a fuzzy conditional statement. A set of fuzzy pairwise similarities is generated and used to evaluate five similarity graphs: a Total Graph (based on all 17 variables) and graphs based on relevant specific subsets of variables, Economic, Environmental, Social and Corporate Governance graphs. The topologies of these graphs are significantly different. No prior knowledge of fuzzy reasoning is required.

1. Introduction

Developments and applications of corporate sustainability (CS), create challenges in solving a broad spectrum of tasks, e.g. forecasting and optimization of ecological related problems. There is no need to prove that CS is an important task. The modelling and optimisation of CS in a real-world environment is often based on only vague and sparse knowledge. A severe information shortage often eliminates statistical methods (Aznarte et al., 2011; Tabachnick et al., 2001). The key condition of the correct application of the test of independency and the correlation matrix is the normality and the minimum number of data sets which corresponds to the required accuracy; for details see (Mathews, 2005; Ross, 2010). Realistic CS problems are complex, integrated, ill-known and usually difficult and expensive to measure/quantify. They may be subject to complex relations with their surroundings, which may make it nearly impossible to isolate them without a substantial distortion of the available knowledge. This is the key reason why it is complicated to apply statistical methods to CS related tasks.

The only absolutely objective means of a probability evaluation of an event is to repeat the measurement/observation of the outcome of the event infinitely many times under the same conditions. However, this is practically impossible. Subjective quantifications of different types of vagueness have been introduced into economics in general and into production economics in particular (Vesely et al., 2016; Govindan et al., 2013; Phillis and Andriantiatsaholiniaina, 2001).

These are the most important reasons why new formal tools are required for the study of corporate sustainability tasks; keeping in mind that the CS model must not be oversimplified nor too specific. The paper presents an attempt to use fuzzy logic to integrate shallow and sparse CS knowledge items into an applicable formal model using (very) small company data sets.

Sustainable development indicators have been produced for various purposes by a wide spectrum of institutions, resulting in a diverse number of indicators. However, using an adequate and consistent set of indicators to measure sustainable development for a community, a country, or the world is not easy (Baumgartner, 2011; Liu et al., 2016). It requires competencies about the level of viability of the systems involved and their contribution to sustainable development. For example, the United Nations or European Union

* Corresponding author.
E-mail addresses: docekalova@fbm.vutbr.cz (M. Pavláková Dočekalová), doubravsky@fbm.vutbr.cz (K. Doubravský), dohnal@fbm.vutbr.cz (M. Dohnal), kocmanova@fbm.vutbr.cz (A. Kocmanová).

http://dx.doi.org/10.1016/j.ecolind.2017.02.038
1470-160X/

uses economic, social, environmental, and institutional indicators to measure sustainability (Liu et al., 2016).

Sustainability does not represent the endpoint of a process; rather, it represents the process itself. The main goal of sustainability research should be to contribute to our understanding of sustainability problems and to develop and help implement solutions to solve these problems (Baumgartner, 2011).

2. Complexities of corporate sustainability

In order to model complex sustainability indicators (SI) systems effectively, all the available information must be used (Rodrigues et al., 2016; Ahi et al., 2016; Iddrisu and Bhattacharyya, 2015). Information knowledge items based on verbal quantifiers are examples of tasks that are difficult to incorporate. Even very uncertain SI knowledge is valuable. It is the effectiveness with which uncertain knowledge is used which is very often the main distinction between good and bad models of the same system.

Sustainability indicators and processes of their evaluations/quantifications are complex and integrated. Therefore, knowledge of such processes may be inconsistent, sparse, and uncertain and represented by different formal tools.

Many different environment related activities, e.g. feasibility or cost analyses, assessment of environmental impact, depend heavily, if not exclusively, on old records (Iddrisu and Bhattacharyya, 2015; Shmelev and Rodríguez-Labajos, 2009). Their revitalization and/or upgrade is necessary in order to make these data as useful as possible. Any SI analysis heavily dependent on industrial experience may be partially inconsistent or contradictory (Distaso, 2007; Mayer, 2008). If the experience itself is inconsistent then the formalized knowledge base is inconsistent as well. Revitalization activities are not capable of creating new objective information as they do not include experimentation. No substantial increase in information content can thus be expected as a result of the revitalization activity.

Revitalizations of a formalized network of knowledge items can be represented by the following sequence of activities:

- identification of inconsistencies and/or redundancies;
- partial or complete eliminations of inconsistencies and redundancies;
- addition of non-formalized knowledge, e.g. experience, to the formalized knowledge.

These revitalizations must be based on applications of knowledgeable engineering methods. Even a subjective refutation of knowledge or data can increase the flexibility and reasoning power based on this knowledge (Rodrigues et al., 2016; Ahi et al., 2016; Dohnal and Kocmanova, 2016).

It is a well-known fact that information, e.g. experimental results, obtained from different sources as a result of a literature survey are often not consistent (Dohnal and Kocmanova, 2016). If the level of inconsistency exceeds a certain threshold value, it cannot be explained by inaccuracies of measurement or by the fact that the literature sources do not present complete experimental or operational details. In this case, a systematic identification of all inconsistencies is the first step towards a better understanding of the problem under study.

Experience, sparse industrial observations and expert guessing represent a very important source of SI knowledge that cannot be formalized using conventional formal tools – classical mathematics and statistics traditionally used in SI studies. Such vague knowledge can however be partially formalized and consequently incorporated into the main body of knowledge using up-to-date formal calculi such as fuzzy and rough sets, fractal analysis, qualitative, semi-qualitative and order of magnitude reasoning, (for details see Dohnal, 2016).

Table 1
Economic, environmental, social, and corporate governance indicators of corporate sustainability.

Economic indicators
Cash Flow (*eco1*)
Return on assets (*eco2*)
Environmental indicators
Consumption of recycled materials and raw materials (*envi1*)
Fuel consumption (*envi2*)
Waste production (*envi3*)
Environmental costs (*envi4*)
Social indicators
Wage discrimination (*soc1*)
Violations of the Code of Ethics (*soc2*)
Percentage of employees covered by a collective agreement (*soc3*)
Occupational diseases (*soc4*)
Percentage of products and services for which the impact on the health and safety of customers is evaluated during their life cycle (*soc5*)
Expenditures on identifying and ensuring customer satisfaction (*soc6*)
Corporate governance indicators
Percentage of strategic goals achieved (*cg1*)
Percentage of women in CG (*cg2*)
Contributions to political parties, politicians and related institutions (*cg3*)
Number of complaints received from stakeholders (*cg4*)
Total number of sanctions for noncompliance with laws and regulations (*cg5*)

A network of mutually connected SI and managerial items and data of knowledge, when observed by experts, is often interpreted in terms of personal experience and analogies. These analogies can represent a substantial increase in the quality of knowledge, such as discriminative power, which could result in the formation of a better knowledge base. This is the only external source of additional information that can be incorporated in revitalized knowledge. Any analysis of such types of knowledge is beyond the reach of the conventional and formal tools traditionally used in SI studies.

3. Corporate sustainability measurements

The definition of CS is built on the definition of the macroeconomic concept of sustainable development (WCED, 1987) and is based on a balance between the environmental, social, economic, and corporate governance pillars (Pavláková Dočekalová and Kocmanová, 2016; Eccles et al., 2012; Elkington, 1997).

The methodology presented in this paper is applied to the Complex Performance Indicator (CPI) which integrates environmental, social, economic, and corporate governance performance. There are 70 potentially relevant parameters (Pavláková Dočekalová and Kocmanová, 2016). A substantial decrease in the number of parameters was done in order to reduce the information demand of the CPI (for details see Pavláková Dočekalová and Kocmanová, 2016).

The following economic, environmental, social, and corporate governance variables were chosen by a team of experts as the key factors, which express corporate sustainability:

The statistical analysis identified two economic variables (for details see Pavláková Dočekalová and Kocmanová, 2016). In other words, just two variables are sufficient to study economic performances. On the other hand, social and CG performances are much more heterogeneous when influencing a broad spectrum of stakeholders. This is the key reason that 65% of the variables in Table 1 included in the model of complex performance (CPI) relates to social and CG areas.

There are basically two different methodologies for solving realistic CS problems:

- common sense (minimal formal calculations, back-of-the-envelope philosophy),