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ORIGINAL PAPER

Parsimonious use of indicators for evaluating sustainability systems with multivariate statistical analyses

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Abstract Indicators are commonly used for evaluating relative sustainability for competing products and processes. When a set of indicators is chosen for a particular system of study, it is important to ensure that they vary independently of each other. Often, the number of indicators characterizing a chosen system may be large. It is essential to select the most important indicators from a large set so that a dependable bias-free analysis can be done using the reduced set of indicators. In this paper, we propose the use of principal component analysis (PCA) along with the partial least square-variable importance in projection (PLS-VIP) method to ensure that the explicit or tacit assumption of the independence of the chosen indicators is valid. We have used two case studies to demonstrate successful use of these two methods for parsimonious use of indicators for sustainability analysis of systems.

Keywords Principal component analysis (PCA) · Partial least square–variable importance in projection (PLS–VIP) · Sustainability · Indicators · Multivariate statistical analysis

Introduction

It is generally agreed that systems should be evaluated for their relative sustainability using quantitative indicators or metrics, terms that are used here interchangeably. Typically, indicators for the purpose of sustainability assessment are chosen using the standard Bruntland model of the three sustainability domains of environment, economy, and society. There have been several attempts to evaluate industrial systems for sustainability with quantitative indicators (IChemE 2002; AIChE 2003; Shonnard et al. 2003; Zhou et al. 2012). A standard list of indicators that applies to all systems of concern, however, cannot exist as the systems differ from each other in system type, scale, and properties. Nevertheless, even when the chosen indicators are deemed commensurate for a particular system of study, it is important to recognize that they should be independently variable. This feature is important because it helps in removing bias introduced from multiple uses of similar indicators. When the number of indicators is large, the task of sorting them into a necessary and sufficient number of metrics is essential for dependable analyses.

Even when the number of indicators is limited, comparing alternatives for relative sustainability can still be difficult owing to very frequent occurrences of the favored option not enjoying superior numerical values for all chosen indicators. It was demonstrated earlier that aggregating the indicators into a single index is an easy way to enable decision making on relative sustainability (Sikdar 2009; Sikdar et al. 2012). Two methods were successfully used, one based on Euclidian distances of alternate candidates from a common reference point and the other on geometric mean of the ratios of individual indicator values of a candidate option and those of the chosen reference. Both methods are based on the consideration that a multidimensional indicator space characterizes the system and the various system alternatives are points in that space. The task is then to determine the distance between these point systems and a properly chosen reference point. Relative distances are quantitative representations of relative sustainability.

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