

A method for decision making using sustainability indicators

Raymond L. Smith · Gerardo J. Ruiz-Mercado

Received: 19 December 2011 / Accepted: 29 October 2013
© Springer-Verlag Berlin Heidelberg (outside the USA) 2013

Abstract Calculations aimed at representing the thought process of decision makers are common within multiobjective decision support tools. These calculations that mathematically describe preferences most often use weighting factors for each desire or objective to combine various utility scores onto a single scale to allow a ranking of alternatives. However, seldom are the tradeoffs implied in creating a single scale for multiple objectives described explicitly. This paper illustrates how choices for combining utility scores are in fact a statement of equivalence between the weighted utility scores of these objectives, even if the choice of weighting factors was intended to be value free or “equal weighting.” In addition, relationships between objectives, perhaps developed by stakeholders, can be rewritten as a series of equations (i.e., relationships) for the weighting factors, where it should be noted that seldom will stakeholders provide a set of relationships that exactly match the number of unknowns. Depending on the number of relationships specified, the weighting factors can be underdetermined, unique, or overdetermined. Calculations using the singular value decomposition method can be used as a general method to determine the weighting factors for each of these situations, allowing for explicit representations of the implied tradeoffs for decision makers. Finally, a simple but powerful method for calculating total utility using marginal rates of substitution between utility scores rather than weighting factors is presented. In addition to

using marginal rates of substitution, the calculation of utility can be done with (process) attribute values or using EPA’s GREENSCOPE tool sustainability indicator scores. Utility calculations based on these more intuitive factors (marginal rates of substitution, attribute values, and/or GREENSCOPE indicator scores) can then be used to evaluate various alternatives. The decision maker can see the effects of changing the marginal rates of substitution (i.e., utility tradeoffs) and attribute (i.e., design or operating parameter) values or GREENSCOPE indicator scores for alternatives. While an example from chemical production for terephthalic acid is presented, the methods shown are generally applicable.

Keywords Decision making · Weights · Multiobjective · Marginal rates of substitution · Singular value decomposition · Sustainability indicators · GREENSCOPE

Preface

Decisions are intended to align people’s actions to their desires. One cares about the decision because of the value placed on the consequences. In this sense, the values are the fundamental objectives to be achieved. Keeney (1992) expressed this as value-focused thinking rather than the more common alternative-focused thinking. One of the bases of value-focused thinking is that by broadening the context of the situation a decision problem becomes a decision opportunity—an opportunity to achieve valued objectives. However, alternative-focused thinking is the problem-analysis framework within which most people live, which is to make the best of the alternatives presented. We preface this work by stating our belief in value-focused

The views expressed in this article are those of the authors and do not necessarily reflect the views or policies of the U.S. EPA.

R. L. Smith (✉) · G. J. Ruiz-Mercado
National Risk Management Research Laboratory, U.S.
Environmental Protection Agency, Office of Research and
Development, Cincinnati, OH 45268, USA
e-mail: smith.raymond@epa.gov