XVIII ICIEOM 2012
International Conference on Industrial Engineering and Operations Management
Guimarães - Portugal
July 9 - 11, 2012

A Review of Value Tools Used in Sustainability Assessment

Guilherme Petry Breier*, Istefani de Paula*, Carla ten Caten*, Ângela M. F. Danilevicz*, Carlos Fernando Jung*

* Production Department, School of Engineering, Federal University of Rio Grande do Sul, 90035-190 Porto Alegre, Brazil

Email: gpbreier@producao.ufrgs.br, istefani@producao.ufrgs.br, tencaten@producao.ufrgs.br, angelamfd@producao.ufrgs.br, jung@producao.ufrgs.br.

Abstract

This paper aims to provide a concise overview on methods used for assessing progress in sustainable environments, and introduce the concept of indexes and indicators used in assessing the impacts on achieving this sustainability. The assessment of such indices and indicators aims to provide guidance regarding the validity of its use for quantification of changes towards sustainability. In this context the methods of assessing sustainability have the challenge to measure, analyze and suggest solutions to a diverse set of parameters that affect the stakeholders involved. However the methods of assessing sustainability still need a higher maturity when compared with rates of environmental impact assessment (EIA) and environmental strategy assessment (SEA). In particular, this paper will be presented a comprehensive review of the major indices and indicators for assessing sustainability with a focus on economic value, and the feasibility of incorporating them in the analysis of value. The review includes methods of sustainability indicators and composite indices of sustainability that have been researched in various areas such as social sciences, engineering, ecology and economy.

Keywords: Sustainability. Value Tools. Indicators

1 Introduction

The concept of sustainability emerged in the early 70's (IUCN, 1980) but became known to the world only when the environment and development report was written by the World Commission on Environment and Development (WCED, 1987). Various definitions have been proposed since then (PEZZOLI, 1997) but after more than 25 years of debate, there is a consensus that the term sustainability should encompass (PEZZOLI, 1997): (i) the integration of elements such as economy, environment, social and institutional issues, considering their interdependency; (ii) consider the consequences of actions taken today on the future; (iii) acknowledging the presence of uncertainties on the models and acting in a more cautious way; (iv) the participation of society on decision making.

However, considering the difficulty and the complexity of the methods and models to assess specific sectors and systems in our society, the focus of sustainability assessments inevitably becomes a task hard to accomplish. In this context, emerge in the literature simplified models that exclude certain indicators and/or parameters from the global concept of sustainability. Many of the sustainability assessment models and methods rely on various simplified assessment methodologies and tools (BREIER *et al.,* 2011). Munda (2006) comments on the characteristics of the reductionist paradigm for the creation of descriptive models, such as the use of a single measurable indicator (e.g. GDP per capita), a single dimension (e.g. economic dimension, as the triple bottom-line), a single analysis scale (e.g. economic impact), a single goal (e.g. the maximization of economic efficiency) and a single time horizon. Another characteristic that exemplifies very well this reductionist paradigm is the trend to quantify and aggregate the different sustainability dimensions with a single measurement unit (e.g. quantifying the parameters through a financial value). Unfortunately, despite many criticisms being pointed out in various researches, the assessment process through simplified methods and models is the dominant paradigm when taking about the sustainability assessment of productive sectors.

As an advantage of the assessment method, its simplicity stems out from its ease of use, since its trend of reducing the manifoldness of environmental impacts of the human activity to a group of limited figures,

results in an integrated index of human and environmental concerns for the decision making (COSTANZA, 2000).

In fact, the majority of methodologies and tools discussed in this paper were not made exclusively for sustainability assessments of certain kinds of sectors and systems, as they present good flexibility and adaptation to all examples submitted, to the point that it can assess sustainability in a more comprehensive fashion. The simplified methodologies, as well as the tools, may produce a good amount of information at first, providing very significant data for the debate on sustainability (MUNDA, 2006).

In this context, the objective of this work is to provide a concise overview in the context of methodologies and to evaluate its potential in advancing sectors and systems towards sustainability and introduce the concept of indexes and indicators currently used in order to evaluate the impacts of sustainability deployed.

The selection process for these indices and indicators follows some elements of a bibliometric survey, with search in the database Web of Science.

The various current proposals are assessed primarily with the criteria outlined above aggregates of some operating points suggested by Lee (2006). This article is divided into six sections. The first section presents the assumptions for the construction of this work. The second section gives a brief theoretical literature on research. In the third section presents the concepts of sustainability indicators and indices, while the fourth section presents the results of steps from a bibliometric survey. Based on the results of the previous step were identified monetary quantification methods for evaluating the sustainability, which are described in section five, and a review of these methods. In the sixth and final section presents the conclusions and pointed out new opportunities for research.

2 Methodological Procedures

This study was divided into three main stages, shown in the Figure 1.

Figure 1: Stages of development of the article

The first step followed by some activities of the research method proposed by bibliometric (Neely, 2005). The goal of a bibliometric survey is to identify the authors who are studied through citation analysis, co-citation and references (Neely, 2005). Vanti (2002) explains that bibliometrics is a quantitative technique that has purpose to classify and measure the yield and quality of authors in a particular subject, by the numbers of publications and citations of different researchers, and allow the identification of key authors, the journals most important, by author or production by country, as well as checking the collaboration between the authors analyze the citations and co-citations, check the growth and decline of themes, or emergence of new issues.

Initially the activity was performed selection of the database that aims to choose a good reference work for the study proposed here. Next, we performed the activity definition the key words references to make the research.

The survey should make new refining activities in order to include the research area. Based on the findings of the bibliometric survey conducted, it moved to the second stage of labor, to seek the understanding of differences and/or complementarities between composite indices and indicators for assessing sustainability. This analysis allows us to correctly understand the meaning of each of these terms and how they can be composed.

The third step, identification of monetary quantification methods for sustainability assessment is performed based on the results from the survey and the definitions of bibliometric indices and indicators.

3 Bibliometric Research Results

The search for works that compose this research was done on the Web of Science database, which is the database recommended by Medina (2011) for the use of the Sitkis and UCINET programs.

On the first stage, works that contained the keywords like "sustainability", "sustainability indicators", "sustainability assessment" and "value tools for Sustainability assessment" were searched, summing up 578 works, what can be observed in Figure 2. The survey was refined for choosing only articles published in magazines and that included the area of environmental engineering.

Field: Web of Science Categories	Record Count	% of 578	Bar Chart
ENVIRONMENTAL SCIENCES	161	27.855 %	
ECOLOGY	92	15.917 %	
ENVIRONMENTAL STUDIES	68	11.765 %	
ENGINEERING ENVIRONMENTAL	58	10.035 %	
AGRICULTURE MULTIDISCIPLINARY	36	6.228 %	
ECONOMICS	35	6.055 %	
WATER RESOURCES	35	6.055 %	
BUSINESS	33	5.709 %	
MANAGEMENT	31	5.363 %	
FORESTRY	29	5.017 %	

Figure 2: Number of publications on the basis of the search

In order to reduce the research, it was chosen only scientific papers to be selected, when 421 papers remain about the keyword select.

Another filter used was the search for papers in the Engineering Environment area, what resulted in a total of 55 papers. Those results were classified by relevance order and afterwards by ordination, the abstracts were read, and 25 papers that used value tools selected, which were then used in the weighting of the sustainable indicators included in this review.

4 Indicators and Indexes Composed for the assessment of Sustainability

This section presents the differences between indicators and composite indices for evaluation of sustainability.

4.1 Indicators

Indicators have been used in many fields of the human knowledge for the purpose of measuring, assessing and planning different actions and phenomena. They have been the central subject of debate on sustainability among a great number of national and international organizations and academic institutions that conduct important researches in the field. The reasons for their popularity are that the indicators may offer important guidance to decision making in different ways. They can translate knowledge of physical and social sciences in manageable information units which, in turn, may facilitate the decision making process. They can help measuring and calibrating the progress towards sustainability goals (UN, 2001).

Gallopin (1997) documented a series of different meanings that were attributed to the concept, including variables, parameters, value measurements and reality empirical models, among others. In this definition of an indicator as a variable, it is an operational representation of a system's attribute. The value of these variables is the real measures or observations in different moments, places, populations etc. or the

combination of these. It becomes immediately evident that there is no one single indicator (e.g. GDP) that can comprise all the aspects of complex concepts, such as sustainability itself. However, a collection of indicators chosen and analyzed, under certain criteria, is the best way to describe these complex concepts and systems.

4.2 Composite Indexes

The composite indicator (CI) may be simply defined as an aggregation of different indicators with a well-developed and predetermined methodology. Thus, a CI is on top of an information pyramid (HAMMOND *et al.,* 1995), as illustrated on Figure 3. Adding various indicators to a single CI conceptually differs from the techniques based on other indicators, such as the multi-criteria analysis, where the constituent indicators are not added to a single number. The CIs are becoming more and more popular for sustainability assessment in many scales (VAN DIJK and MINGHSHUN, 2006; KRAJNC and GLAVIC, 2005; PRESCOTT-ALLEN, 2001).

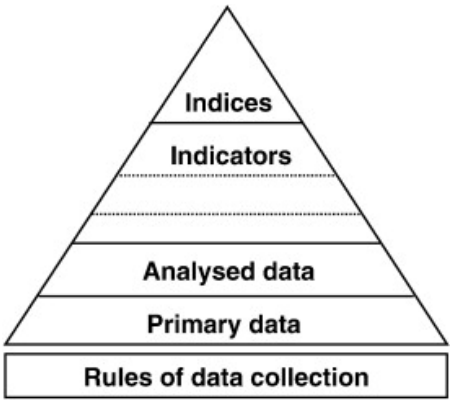

Figure 3: The Pyramid of Information (Hammond et al., 1995)

The CIs can be divided in many different categories according to the many methodological choices made during the formulation. The classification of these categories may be used according to the information flux that may fuel with information the bottom-up or top-down method (NIEMEIJER, 2002). The bottom-up approach is preferred when the availability of data is a central concern for the CI development and the quality of data is high for all selected indicators. On the other hand, the top-down approach is used when the best possible indicators are selected to accommodate a CI from the theoretical standpoint, while the data availability is only one of the many considered aspects. The main attracting and critical characteristics of CIs are summarized on Table 1.

Table 1: Attracting and critical characteristics of CIs (Nardo *et al.,* 2005)

Attracting Characteristics	**Critical Characteristics**
May summarize complex and multidimensional issues.	May generate false indications if poorly constructed.
Easier to interpret.	May produce simplistic conclusions.
Facilitates the task of classification of alternatives throughout time in complex issues.	May be underused, e.g. to support a desired policy, if the construction is not transparent and there are no solid statistical and conceptual principles.
Reduces the size of an indicator group or including more information inside the existing size limit.	The selection of indicators and weights could be a target to political challenge.
Puts questions of performance and progress issues at the center of the political arena.	May mask severe failures in some dimensions and increase the difficulty in identifying adequate corrective measures.
Facilitates communication with general public and promotes accountability.	May lead to political inadequacies if the performance dimensions, which are easy to measure, are ignored.

The challenge for the coming years is to work on an acceptable weighting theory, in which the weight that is essentially value judgment may present a greater significance, regardless of the value attributed in the

context of the particular composite indicator (OECD, 2003). Techniques such as the Analytical Hierarchy Process (AHP) and the Conjoint Analysis (CA) are participative process where the selected participants (audience and/or specialists) are directly invited to speak on the importance of sustainability issues represented on the index composition. Other weight assignment techniques that involve the stakeholders and that use statistical methods may be used in order to produce the weights.

5 Monetary Methods for Sustainability Assessment

Concepts and methods deriving from economy literature and, specially, from the welfare, development, environment and more recently the economics ecology principles have been used since the beginning of the debate on sustainability, to explain both its theoretical basis and its policies and recommendations (ALBERTI, 1996). It is important to highlight that the economics literature is rather wide and that this work does not intend to present a comprehensive review of it, but it has the goal of offering − due to the number of references in the scientific papers researched on the Web of Science database − ideas on the approaches and presuppositions of three tools that have a potential for sustainability assessment, presenting a higher level of use on the articles selected for the bibliometric review. (i) - Contingent Valuation Method (CVM); (ii) - Cost Benefit Analysis (CBA); (iii) - Index of Sustainable Economic Welfare (ISEW).

The main question in these researches refers who is not going to use money as sustainability assessment metric in the economic world. Pearce et al. (1989) arguments that money may perform a significant role in the assessment of growth or sustainability, provided that money is a good indicator, not only of the audience's preference in funding, but also of the intensity of this preference. Another argument is that the money values tend to be more easily understood by non-specialists and stakeholders.

On the other hand, the monetary analysis of sustainability was rejected mainly for ethical reasons and to the fact that it can lack good judgment in some cases (HEINZERLING and ACKERMAN, 2002). Another relevant criticism is its excess of dependency on subjective assessments. An immediate implication of that is that certain monetary assessments would be valid only if the evaluators had perfect information on the operation and interrelationships of the system under study. However, this is not generally the case, due mainly to scientific uncertainties in many relevant fields of environmental and social sciences.

5.1 Contingent Valuation Method (CVM)

The goal of CVM is finding out the preference declared by the audience about a good or service, measuring the willingness of the audience to pay for this specific good or service (Willingness to Pay, WPT) or its willingness to accept some kind of compensation for the loss of this same good or service (Willingness to Accept, WTA) (ARROW *et al.,* 1993).

With the aim of attributing money value, a hypothetical business is created and a money value is elaborated through the audience by means of direct questions in the form of surveys based on questionnaires and interviews.

As the result of this methodological procedure, the CVM is theoretically capable of assessing a great number of sustainability questions that cannot be assessed by other value tools. Some of the questions that were quantified and aggregated to the tool in the last years include green urban spaces (TYVAINEN, 2001; JIM and CHEN; 2006), the water quality of urban rivers (BATEMAN *et al.,* 2005), urban noise (FOSGERAU and BJORNER, 2006), water quality (ATKINS and BURDON, 2005), biodiversity (CHRISTIE *et al.,* 2005), health (HABBNI *et al.,* 2006; JOHANNESSON *et al.,* 1996; MATARIA *et al.,* 2006) and education (STAIR *et al.,* 2005). Through the readings of these references it is clear that the main criticisms revolve around two concerns: validity and reliability.

One of the main concerns related to reliability of the CVM surveys refers to the possibility of generalizing the survey results. Since, in theory, it is possible to elaborate the value through the study of CVM, it would be possible to generalize and predict the preference declared on other case studies contextually similar.

The majority of studies point out that this preference for benefits is possible under certain circumstances (BATEMAN *et al.,* 2002) but generally this is not reliable (KIRCHHOFF *et al.,* 1997).

The majority of researchers that work with CVM believe that the problems cited above derive from the research project and could be avoided with a better structuration of the questionnaire. A number of different and relevant suggestions is found in the literature (ARROW *et al.,* 1993; BATEMAN and TURNER, 1993) and classified by Venkatachalam (2004).

5.2 Cost Benefit Analysis (CBA)

The Cost Benefit Analysis (CBA) is one of the most used value tools, being an instrument of political assessment which has been gaining prominence in the last decades. Despite the fact that the CBA as a generic tool can be adapted to use different metrics besides the specific monetary value (TAYLOR, 2001); it has been sporadically used for sustainability assessments. The CBAs are realized during the initial planning stage of a project, in order to determine its feasibility, being generally used to answer two important questions: whether a particular project of a certain product should be made or if among a series of projects of products which should be made.

Assuming that there is always people that win and lose with the definition of a project policy, these questions are answered through a comparison between the sum of benefits of the quantified proposals with a disposition of the winner paying for the benefit and the sum of the quantified costs forecasted of the loser accepting the willingness to pay these costs. The project resulting on the improvement of greater welfare for the affected social agents is the most acceptable.

The CBAs generally use one or more assessment tools included in Table 1 for defining the applicable costs and benefits value. However, this monetization may also include uncertainties that compromise the quality of a CBA.

In a scenario that may have many problems influencing the assessment of sustainability and a series of social actors included, the CBA may end up being a great value analysis tool.

However, three major problems arise when handling the tool's costs and benefits: valuation, depreciation, and aggregation. From these three, the assessment is made by the CVM commented on the previous section. The higher the depreciation rate, the higher the devaluation of a good or product, therefore, the possible future impacts get nearer the current period (HOWARTH, 1996). As the results of future impacts have little importance on projects with a long term horizon, this might be seen as contrary to the interest of future generations, taking into account a non-equitable distribution of costs and benefits in the long term, forcing future generations to bear an disproportionate cost in relation to the real value of the current product (PEARCE *et al.,* 1989). In order to bypass this situation, lower depreciation rates have been used for projects that are going to affect many future generations (DALY and COBB, 1989).

Munda (1996) expresses a much more important restriction for using weights on CBA deriving from the linear aggregation of the CBA approach, thus making the requirements lose some of their value, with the adoption of a relationship meaning by trade-offs. According to Zerbe et al. (2006) the Kaldor-Hicks criterion current version is characterized, among others, by the fact that the equity considerations are disregarded. Similar results in relation to inadequacy of Kaldor-Hicks criterion, especially in what concerns the environmental and sustainability heritage, are commented by Farrow (1998).

5.3 Index of Sustainable Economic Welfare (ISEW)

The Index of Sustainable Economic Welfare (ISEW) (DALY and COBB, 1989), the Progress Indicator (GDI) (Redefining Progress, 1995) and the Sustainable Net Benefit Index (SNBI) (LAWN and SANDERS, 1999) are indexes inherently related to the sustainability framework applied to accountancy (PULSELLI *et al.,* 2006). All of the three were developed in order to improve the welfare and bring the sustainable economic value closer to a particular population.

The first step of the ISEW methodological approach is weighting the population's personal expenditure with an index of income inequality. Later this value is modified by addition and subtraction from the monetary values of a predetermined group of factors that may affect the population's general welfare in a positive or negative way. Such factors include a wide range of environmental, economic and social issues, such as the costs of commodities, environmental pollution, criminal rates, unemployment and leisure time (DALY and COBB, 1989). The increase of ISEW levels through time brings about growing welfare and a positive evolution on the sense of sustainability as a result, and measures that promote this increase should be favored.

However, ISEW has also faced significant criticisms (DIETZ and NEUMAYER, 2006). Criticisms on ISEW revolve around two main axes: the lack of theoretical validity and the tendency that some of its proponents have in considering it as a validation of the threshold hypothesis advocated by Chilean economist Marx-Neef (1995). This presupposition affirms that for the whole society there seems to be a period in which economic growth brings improvement to the quality of life, but only to a certain point, from this threshold, if there is no economic growth the quality of life may start to decline (MAX-NEEF 1995).

5.4 Analysis monetary methods for sustainability assessment

A significant advantage of indicators against all other approaches reviewed in this paper is its greater precision in assessing/quantifying the different sustainability issues under the scope, since these issues do not need to be translated to other metrics. Nevertheless, the composite index is greatly influenced by the choice of indicators.

Despite their differences in scope and methodologies, CBA and ISEW share a very important characteristic. Both tools are based on the weak sustainability perspective. The CBA, for instance, seeks at maximizing the welfare of the different social actors, allowing exchanges among different monetary amounts. The replacement derives from the adoption of an equal weighting and aggregation, resulting on trade-offs for the weights. These compensations between costs and benefits result in a weak sustainability, in the sense described above. Similar conclusions may be drawn for the ISEW, where the maximization of the index through time will result in a progress for a more sustainable society.

Most tools analyzed in this work are rather flexible, capable of considering various economic issues, environmental and social sustainability. In addition to the ISEW that contains a standard group of sustainability issues, all other tools will depend on the ability of analysts and stakeholders of choosing which parameters seem more adequate in the context of their study. Moreover, all tools, except ISEW, are capable of analyzing and forecasting future impacts under different development scenarios. Spatial and temporal limits may be assigned by analysts and stakeholders, but the limits are extended and should result in great uncertainties that may have significant implications in the decision process. When it comes to the precautionary principle, value analysis tools are not capable of encompassing all criteria. They seem to take on certainty using monetized values (the exact effect of an impact on sustainability on the social parameter may be quite uncertain or even unknown), where, by definition, certainty does not exist. In addition, most of them generally use the same weights for cost and benefit, what results in a perspective of neutrality of risk, instead of an aversion to risk. Composite indexes may consider the precautionary principle aspects for specific methodological choices, especially in a choice of indicators, weighting and procedures of standardization. Some value assessment tools are participative in the sense that they capture the audience's declared preference on certain sustainability questions in monetary terms. For instance, in the CVM the audience is directly asked about their WTP/WTA on different sustainability questions. Composite indexes may also be participative tools, depending on the methodological choices made. Steps in which the audience may be involved include the choice and weighting of indicators that constitute the composite index. Whether or not CBA may handle equity is questionable, since CBA is based on economic efficiency, and not equity considerations.

Nevertheless, despite its advantages, a growing disenchantment with the applicability of reductionist metrics and tools is observed for sustainability assessment (GASPARATOS *et al.,* 2007). One of those

criticisms comes from the complexity theory and its opinion that these systems, ecosystems, societies and cities are complex and adaptive. Moreover, the belief that it is essential to describe complex systems through the synthesis of its different perspectives is not reducible, adds to the disenchantment on the validity of reductionism on the sustainability assessment. Consequently, they were severely criticized in the past as inadequate for making sustainability policies, for example, (MUNDA, 2006), among others. Some of the proposals to assess sustainability in a non-reductionist way are presented in different frameworks of participative sustainability assessment found in the literature, for instance, (BANVILLE *et al.,* 1998; GAMBOA, 2006; GAMBOA and MUNDA, 2007; GUIMARÃES PEREIRA *et al.,* 2003; KALLIS *et al.,* 2006; MADLENER and STAGL, 2005; MUNDA, 2004; MUSTAJOKI *et al.,* 2004; SALGADO *et al.,* 2006). These frameworks indorse the participation of stakeholder in varied degrees and in different stages of the sustainability assessment, and make extensive use of methodologies with multi-criteria for picking the most adequate solution.

6 Conclusions

The metrics (composite indexes and indicators) presented in this article have restrictions to assess sustainability in a holistic way. The need to address the multitude of environmental, social and economic equity concerns with internal and external management in companies, formulates problems that none of the above reductionist approaches can adequately solve individually. Moreover, the need to act with caution and a bias involve the public further confuse an assessment of sustainability. Another implication arises from the fact that the monetary approaches consider the problems of sustainability from different perspectives.

As a result of the above, the choice of metrics and tools should be carried out according to the context and the characteristics that the analyst seeks to highlight. Both analysts and stakeholders need to be informed about the assumptions underlying the methods used. It should be noted that these methodological assumptions are not necessarily disadvantages, but the characteristics that should be known to ensure the transparency of the final result. Finally, since the methods discussed cannot simultaneously satisfy the four perspectives (PEZZOLI, 1997), there is merit in considering the use of a variety of methods to choose which would strongly be affected by the context of the evaluation. Integrating the outputs of a pluralistic approach should be the subject of future research.

References

ALBERTI, M. Measuring urban sustainability Environ Impact Asses Rev, 16 (1996), pp. 381–424

ATKINS, D. BURDON. An initial economic evaluation of water quality improvements in the Randers Fjord, Denmark. Mar Pollut Bull, 53 (2005), pp. 195–204.

BANVILLE, M. LANDRY, J.M. MARTEL, C. BOULAIRE. A stakeholder approach to MCDA. Syst Res Behav Sci, 15 (1998), pp. 15–32.

BATEMAN, R.K. TURNER. Valuation of environment, methods and techniques: the contingent valuation method.

BREIER, G. P. TEN CATTEN, C, JUNG C. F. Análise dos principais metodos e indicadores aplicados em processos da indústria eletroeletrônica. ENEGEP 2011.

TURNER (Ed.), Sustainable environmental economics and management: principles and practice, Belhaven Press, London (1993), pp. 120–191.

CHRISTIE, N. HANLEY, J. WARREN, K. MURPHY, R. WRIGHT, T. HYDE. Valuing the diversity of biodiversity. Ecol Econ, 58 (2005), pp. 304–317.

COSTANZA. The dynamics of the ecological footprint concept. Ecol Econ, 32 (2000), pp. 341–345.

DALY. Beyond growth. Beacon Press, Boston (1996).

DALY, J.B. COBB JR For the common good. Beacon Press, Boston (1989).

DIETZ, E. NEUMAYER. Some constructive criticisms of the Index of Sustainable Economic Welfare.

FARROW. Environmental equity and sustainability: rejecting the Kaldor–Hicks criteria. Ecol Econ, 27 (1998), pp. 183–188.

FISHER Nature of Capital and Income A.M. Kelly, New York (1906).

FOSGERAU, T.B. BJORNER Joint models for noise annoyance and willingness to pay for road noise reduction Transport Res B-Meth, 40 (2006), pp. 164–178.

GALLOPIN. Indicators and their use: information for decision making.

MOLDAN, S. BILLHARZ (Eds.), Sustainability indicators: report on the project on indicators of sustainable development, Wiley & Sons Inc, New York (1997), pp. 13–27.

GAMBOA. Social multi-criteria evaluation of different development scenarios of the Aysén region, Chile. Ecol Econ, 59 (2006), pp. 157–170.

GAMBOA, G. MUNDA. The problem of windfarm location: A social multi-criteria evaluation framework. Energy Policy, 35 (2007), pp. 1564–1583.

GASPARATOS, M. EL-HARAM, M. HORNER. The argument against a reductionist approach for assessing sustainability.

HORNER, C. HARDCASTLE, A. PRICE, J. BEBBINGTON (Eds.), Proceedings of the International Conference on Whole Life Urban Sustainability and its Assessment, Glasgow Caledonian University, Glasgow (2007), pp. 52–65.

GOULDER, R.N. STAVINS. Discounting: an eye to the future Nature, 419 (2002), pp. 673–674.

GUIMARÃES PEREIRA, J.D. RINAUDO, P. JEFFREY, J. BLASQUES, S. CORRAL QUINTANA, N. COURTOIS ET AL. ICT tools to support public participation in water resources governance and planning: experiences from the design and testing of a multimedia platform. J Environ Assess Policy Manag, 5 (2003), pp. 395–420.

HABBANI, W. GROOT, I. JELOVAC Household health-seeking behaviour in Khartoum, Sudan: the willingness to pay for public health services if these services are of good quality Health Policy, 75 (2006), pp. 140–158.

HAMMOND. Engineering sustainability: thermodynamics, energy systems and the environment Int J Energy Res, 28 (2004), pp. 613–639.

HAMMOND, A. ADRIAANSE, E. RODENBURG, D. BRYANT, R. Woodward Environmental indicators: a systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development World Resources Institute, Washington DC (1995)

HARTWICK Deforestation and national accounting. Environ Resour Econ, 2 (1992), pp. 513–521

HEINZERLING, F. ACKERMAN Pricing the priceless: Cost-Benefit Analysis of environmental protection Georgetown Environmental Law and Policy Institute, Georgetown University, Washington DC (2002) Available at http://www.law.georgetown.edu/gelpi/research_archive/cost_benefit_analysis/PricingThePriceless.pdf

HOWARTH Discount rates and sustainable development Ecol Model, 92 (1996), pp. 263–270

IUCN World Conservation Strategy: living resource conservation for sustainable development International Union Conservation of Nature and Natural Resources, Gland (1980)

JOHANNESSON, P.O. JOHANSSON, R. O'CONNOR. The value of private safety versus the value of public safety . J Risk Uncertain, 13 (1996), pp. 263–275.

KALLIS, V. VIDEIRA, P. ANTUNES, A. GUIMARAES PEREIRA, C.L. SPASH, H. COCCOSSIS ET AL. Participatory methods for water resources planning Environ Plann C, 24 (2006), pp. 215–234.

KIRCHHOFF, B.G. COLBY, J.T. LaFrance Evaluating performance of benefit transfer: an empirical enquiry. J Environ Econ Manage, 33 (1997), pp. 75–93.

KRAJNC, P. GLAVIC. How to compare companies on relevant dimensions of sustainability Ecol Econ, 55 (2005), pp. 551–563.

KUNTZ-DURISETI. Evaluating the economic value of the precautionary principle: using cost benefit analysis to place a value on precaution. Environ Sci Policy, 7 (2004), pp. 291–301.

LAWN, R.D. SANDERS. Has Australia surpassed its optimal macroeconomic scale? Finding out with the aid of 'benefit' and 'cost' accounts and a sustainable net benefit index. Ecol Econ, 28 (1999), pp. 213–229.

LEE. Bridging the gap between theory and practice in integrated assessment. Environ Impact Asses Rev, 26 (2006), pp. 57–78.

MATARIA, R. GIACAMAN, R. KHATIB, J.P. MOATTI. Impoverishment and patients' "willingness" and "ability" to pay for improving the quality of health care in Palestine: an assessment using the contingent valuation method. Health Policy, 75 (2006), pp. 312–328.

MAX-NEEF. Economic growth and quality of life. Ecol Econ, 15 (1995), pp. 115–118.

MEDINA, W. P. Bibliometria. Aula do curso de gestão de projetos. Disponível em http://www.producao.ufrgs.br/arquivos/496_bibliometria_conceitos.ppt. Acessado em 12/12/2011.

MUNDA. Social multi-criteria evaluation for urban sustainability policies. Land Use Policy, 23 (2006), pp. 86–94.

MUNDA, M. NARDO. Constructing consistent composite indicators: the issue of weights (EUR 21834 EN) Institute for the Protection and Security of the Citizen, Ispra (2005) Available at http://crell.jrc.ec.europa.eu/Well-being/papers/Munda%20Nardo%20euroreport1.pdf.

MUSTAJOKI, R.P. HÄMÄLÄINEN, M. MARTTUNEN. Participatory multicriteria decision analysis withWeb-HIPRE: a case of lake regulation policy. Environ Model Softw, 19 (2004), pp. 537–547.

NARDO, M. SAISANA, A. SALTELLI, S. TARANTOLA, A. HOFFMAN, E. GIOVANNINI. Handbook on constructing composite indicators: methodology and user guide (STD/DOC(2005)3).

NARDO, M. SAISANA, A. SALTELLI, S. TARANTOLA. Tools for composite indicators building (EUR 21682 EN) Institute for the Protection and Security of the Citizen, Ispra (2005) Available at http://composite-indicators.jrc.ec.europa.eu/Document/EUR%2021682%20EN.pdf.

NEELY, A. The evolution of performance measurement research: developments in the last decade and a research agenda for the next. International Journal of Operations & Production Management. Vol. 25, n. 12, p. 1264-1277, 2005.

NIEMEIJER. Developing indicators for environmental policy: data driven and theory driven approaches examined by example. Environ Sci Policy, 5 (2002), pp. 91–103.

OECD. Quality framework and guidelines for OECD statistical activities: Version (2003) Statistics Directorate, Paris (2003) Available at http://www.oecd.org/dataoecd/26/42/21688835.pdf

OECD Statistics Directorate, Paris (2005) Available at http://www.olis.oecd .org/olis/2005doc.nsf/7b20c1f93939d029c 125685d005300b1/7bef27ea932895d4c1257058004bcdeb/$FILE/JT0018 8147.PDF.

PADILLA. Intergenerational equity and sustainability. Ecol Econ, 41 (2002), pp. 69–83.

PEARCE D, E. Blueprint for a green economy.London: Earthscan Publications Ltd; 1989.

PEZZEY, M.A. TOMAN (Eds.), The economics of sustainability, Ashgate Press, Aldershot (2002).

PEZZOLI. Sustainable development: a transdisciplinary overview of the literature. J Environ Plan Manag, 40 (1997), pp. 549–574.

SALGADO, C.S. QUINTANA, A. GUIMARÃES PEREIRA, L. DEL MORAL ITUARTE, B. PEDREGAL MATEOS. Participative multi-criteria analysis for the evaluation of water governance alternatives. A case in the Costa del Sol (Málaga). Ecol Econ (2006) http://dx.doi.org/10.1016/j.ecolecon.2006.11.008.

SOLOW. An almost practical step towards sustainability. Resour Policy, 19 (1993), pp. 162–172.

STAIR, T.J. REPHANN, M. HEBERLING. Demand for public education: evidence from a rural school district. Econ Educ Rev, 25 (2005), pp. 521–531.

TAYLOR. Employment-based analysis: an alternative methodology for project evaluation in developing regions, with an application to agriculture in Yucatan. Ecol Econ, 36 (2001), pp. 249–262.

VANTI, N. Da bibliometria à webometria: uma exploração conceitual dos mecanismos utilizados para medir o registro da informação e a difusão do conhecimento. 2002. Ci. Inf., Brasília, v. 31, n. 2, p. 152-162.

VENKATACHALAM. The contingent valuation method: a review. Environ Impact Asses Rev, 24 (2004), pp. 89–124.

WCED. Our common future. Oxford University Press, Oxford (1987) Available at http://www.un-documents.net/wced-ocf.htm

ZERBE JR., Y. BAUMAN, A. FINKLE. An aggregate measure for benefit-cost analysis. Ecol Econ, 58 (2006), pp. 449–461.

ZHOU, B.W. ANG, K.L. POH. Comparing aggregating methods for constructing the composite environmental index: an objective measure. Ecol Econ, 59 (2006), pp. 305–311.