Benchmarking: An International Journal

Multicriteria analysis for benchmarking sustainability development

Hepu Deng

Multicriteria analysis for benchmarking sustainability development

Hepu Deng
School of Business IT and Logistics, RMIT University, Melbourne, Australia

Received 15 July 2013
Revised 26 September 2013
Accepted 3 December 2013

Abstract

Purpose – The purpose of this paper is to formulate the process of measuring and benchmarking the performance of sustainability development of organizations as a multi-criteria analysis problem and presents an objective approach for solving the problem in a simple manner.
Design/methodology/approach – An objective approach is developed for benchmarking the sustainability development performance of individual organizations in the context of multi-criteria analysis. The relative importance of the sustainability indicators is determined independent of the subjective preferences of the decision maker using the concept of information entropy. A modified technique for order preference by similarity to ideal solutions is used for effectively incorporating the objective indicator weights into the process of determining the overall performance of sustainability development of each organization. As a result, an unbiased overall ranking of individual organizations on the performance of their sustainability development can be obtained.
Findings – The proposed approach is applicable for measuring and benchmarking the performance of organizational sustainability development through the presentation of an example.
Originality/value – The originality of the paper is on the development of the objective approach within the context of multi-criteria analysis for measuring and benchmarking the performance of sustainability development of individual organizations.

Keywords Performance measurement, Benchmarking, Economic sustainability
Paper type Research paper

Introduction

Sustainability is becoming increasingly important to every organization nowadays due to the rapidly growing world population, the increasing industrial production activities which heavily rely on the consumption of non-renewable resources, and the rapid development of emerging economies (Hart, 1997; Petrini and Pozzebon, 2009; Magee *et al.*, 2013). Organizations worldwide are under growing pressures for actively pursuing sustainability development through the adoption of various sustainability strategies and practices in order to meet the environmental regulations and compliance standards (Bansal and Roth, 2000), to mitigate the environmental impact of their operations (Alaraifi *et al.*, 2013), and to address the environmental concern of various stakeholders (Dyllick and Hockerts, 2002) while at the same time increasing their profitability and improving their competitiveness in the marketplace (Porter and van der Linde, 1995; Brunner and Starkl, 2004).

Sustainability reporting is the process of measuring and benchmarking the performance of sustainability development of individual organizations with respect to a set of specific indicators in a given situation (Atkinson, 2000; Munda, 2005a, b; Lozano and Huisingh, 2011). Due to the increasing recognition of the importance of sustainability development (World Commission on Environment and Development, 1987; United Nations, 1992; Tang and Zhou, 2012), considerable efforts have been made to the increasing adoption of the widespread organizational practice of regular sustainability reporting (Atkinson, 2000; Brunner and Starkl, 2004). Such reporting involves in a broad spectrum of

Benchmarking: An International Journal
Vol. 22 No. 5, 2015
pp. 791-807

1463-5771
DOI 10.1108/BIJ-07-2013-0072

practices of evaluating the organizational sustainability performance from 'top-down' annual reporting against standardized indicator sets with varying degrees of auditing assurance (Brunner and Starkl, 2004), to ad hoc, one-off or semi-periodic assessments against 'bottom-up' and locally grown measures (Fraser *et al.*, 2006; Munda, 2007; Magee *et al.*, 2013). The top-down approach focuses on assessing the performance of sustainability development of an organization with respect to the Global Reporting Initiative indicators and guidelines (Atkinson, 2000; Veleva *et al.*, 2001). The bottom-up approach concentrates on identifying the potential improvement in sustainability development while evaluating the performance of sustainability development of individual organizations (Atkinson, 2000; Agger, 2010). No matter which approaches are used in measuring and benchmarking the performance of organizational sustainability development, an overall performance index for adequately describing the performance of sustainability development of an organization is usually necessary (Munda, 2005a, b, 2007; Lozano and Huisingh, 2011; Tang and Zhou, 2012).

Measuring and benchmarking the performance of sustainability development of individual organizations usually involves in evaluating and comparing the performance of these organizations on sustainability development for finding out how these organizations perform in a relative manner (Cherchye and Kuosmanen, 2004; Munda, 2005b; Lozano and Huisingh, 2011; Tang and Zhou, 2012). Such a study is significant as it allows individual organizations to (a) measure their relative performance on sustainability development, (b) identify the lesson if any that one organization can learn from other organizations, and (c) identify and learn from the best practices among the organizations concerned (Deng *et al.*, 2000; Cherchye and Kuosmanen, 2004; Deng, 2008). As a result, numerous approaches have been developed from different perspectives for measuring and benchmarking the performance of sustainability development of individual organizations (Cherchye and Kuosmanen, 2004; Munda, 2004, 2007; Tang and Zhou, 2012).

Existing approaches have shown their applicability in measuring and benchmarking the performance of sustainability development of individual organizations from different perspectives (Brunner and Starkl, 2004; Munda, 2007; Tang and Zhou, 2012). These approaches, however, are not totally satisfactory as they do not really provide an objective view of the relative performance of individual organizations on sustainability development. Very often different approaches tackle this problem from different perspectives with respect to specific circumstances (Munda, 2004, 2007; Tang and Zhou, 2012). There is not a commonly accepted approach that can lead to the development and publication of a universally acceptable index for measuring and benchmarking the performance of sustainability development of individual organizations. As a result, the resulting indices are not widely accepted due to the selection of specific sustainability indicators (Munda, 2007; Lozano and Huisingh, 2011) and the use of equal or subjective weights for the sustainability indicators (Munda, 2005a, b). To ensure a wide acceptability of such an inter-organizational study outcome on measuring and benchmarking the performance of organizational sustainability development, an overall evaluation of the performance of sustainability development of individual organizations in an objective manner is desirable.

This paper formulates the process of measuring and benchmarking the performance of sustainability development of individual organizations as a multi-criteria analysis problem and presents an objective approach for solving the problem in a simple manner. The information entropy emitted from the sustainability indicator is used for determining the objective weights of the sustainability indicators. A modified technique for order preference by similarity to ideal solution is used for effectively incorporating the objective indicator weights into the process of determining the overall performance of sustainability development of each organization across all the sustainability indicators. As a result, an unbiased overall ranking of individual organizations on their sustainability development performance can be obtained. An empirical study of several leading countries on their sustainability development performance is conducted. The result shows that the proposed approach is effective and efficient for measuring and benchmarking the performance of sustainability development of individual organizations in real world settings.

In what follows, we first review existing approaches on measuring and benchmarking the performance of organizational sustainability development, leading to the formulation of the multi-criteria analysis problem for measuring and benchmarking the performance of sustainability development of individual organizations. We then present an objective approach for measuring and benchmarking the performance of sustainability development of individual organizations, followed by an empirical study of several leading countries on their sustainability development performance for demonstrating the applicability of the objective approach for evaluating the performance of individual organizations on sustainability development in real world settings. Finally a conclusion is presented to summarize the main merits of the proposed approach and its implications for measuring and benchmarking the performance of organizational sustainability development in real world settings.

Measuring sustainability development: towards engaged sustainability reporting

Sustainability can be interpreted from different perspectives in the literature (Costanza and Wainger, 1991; Munda, 2005a, b; Lozano and Huisingh, 2011). Costanza and Wainger (1991), for example, define sustainability as the amount of consumption that can be sustained indefinitely without degrading capital stocks and natural stocks. Hawken (1993) describes sustainability as demands placed upon the environment by people and commerce to reach an economic state, without reducing the environment capacity to provide the same for the future generations. Naveh (1998) shows sustainability as the long lasting mutual and collaborative benefit relationship between the people, the livelihood, and the economy within an open and built-up landscape. Baumgärtner and Quaas (2010) define sustainability as a "normative notion about the way that how humans should act towards nature, and how they are responsible towards one another and future generations". Despite these interpretations in the literature, the most widely used definition of sustainability is the development that meets the needs of the present without compromising the ability of the future generation to meet their own needs (Brundtland Commission, 1987).

The concept of sustainable development is originated from the concern about the sustained productivity of the forest industry in the European continent (Ebner and Baumgartner, 2006). It is related to the pattern of the resource use for meeting human needs in the present as well as for future generations while preserving the environment. Sustainable development is not a fixed state of harmony, but rather a process of changes in developments that require resources, investments, technologies, and institutional changes to meet the present generation needs without compromising the future generation needs (Munda, 2007; Tang and Zhou, 2012). It is the process of achieving the sustainability goal characterized in four sustainability conditions including (a) human needs in that society are met, without increase in (b) concentrations of substances extracted from the earth's crust, (c) concentrations of substances produced by the society, and (d) degradation by physical means (Robèrt *et al.*, 2002).

The concept of organizational sustainability is intertwined with sustainable development (Munda, 2007; Magee *et al.*, 2013). It refers to an organization's ability to meet the current direct and indirect needs of the organization and its stakeholders while being able to meet the future needs of its stakeholders (Donaldson and Preston, 1995; Dyllick and Hockerts, 2002). There are three dimensions to organizational sustainability – economical, social and environmental – which are commonly known as the triple-bottom line (Elkington, 1994). Economic sustainability refers to the capability of an organization to secure its long-term economic performance through maximizing shareholder's returns (Dyllick and Hockerts, 2002). Social sustainability concerns about an organization's long-term responsibility and commitment with respect to its perceived societal obligations and their positive influence on the present and future relationships with its stakeholders. Environmental sustainability focuses on the ability of individual organizations in using natural resources to meet their current needs of the business, without compromising the future needs of other organizations and the society in general (Alaraifi *et al.*, 2012).

With the growing environmental pressure from deteriorating ecological systems, resource scarcity, and industrial pollution, sustainability development has become increasingly important for every organization in different industries (Hart and Milstein, 1999; Veleva *et al.*, 2003). As a matter of fact, organizational sustainability is considered to be a positive multi-faceted concept in a new management paradigm which considers both the organization's economic performance and the environmental protection and social needs and equity (Bibri, 2009; Lo and Sheu, 2007). It is portrayed as a business approach that focuses on the long-term shareholder value creation by embracing opportunities that arise while managing economic, environmental and social risks (Munda, 2007; Dow Jones Sustainability Indexes, 2010; Alaraifi *et al.*, 2012). The pursuit of organizational sustainability developments creates an exceptional source of commercial opportunities for competitive organizations (Elkington, 1998). It challenges many organizations to rethink their current business models for improving and maintaining their competitive advantages (Dunphy *et al.*, 2003). It reflects an organization's capacity for at least sustaining and/or increasing its economic prosperity while maintaining the natural capital over time, without compromising its environmental responsibility and social stewardship (Sahay, 2004).

Tremendous efforts have been spent and significant advances have been made in the development of various approaches for evaluating the performance of sustainability development of individual organizations (Munda, 2007; Tang and Zhou, 2012). Daly and Cobb (1990), for example, present an index-based approach for measuring the sustainability development of individual organizations. Along the same line, Pearce and Atkinson (1993), Vitousek *et al.* (1986), and Wackernagel and Rees (1995) propose several index-based approaches for measuring the organizational sustainability development from various perspectives. Although these approaches have demonstrated their usefulness in evaluating and measuring organizational sustainability development, they are often criticized due to (a) the ad hoc nature of the approach, (b) the need for a common measurement across various sustainability indicators, and (c) the lack of a clearly defined policy objective.

Atkinson (2000) presents an accounting-based approach for measuring organizational sustainability development. Such an approach argues the need for quantitatively valuing the pollution in assessing organizational sustainability development. With an adequate use of costing accounting standards and procedures, the overall sustainability of an organization is evaluated based on the total cost of the pollution caused by an organization. The approach is simple to use, and the rationale behind the approach is sensible and comprehensive. It is capable of quantitatively evaluating the organizational sustainability development with respect to a single objective. This approach, however, ignores the multi-dimensional nature of the sustainability development process (Munda, 2005a, b). Furthermore, the interest of various stakeholders in the sustainability development process is not adequately considered.

Tam (2002) proposes a multi-objective programming approach for evaluating the sustainability development of individual organizations in selecting the best environment design in automotive and manufacturing industries. Such an approach recognizes the multi-dimensional nature of the problem in measuring the sustainability development with a focus on the environment impact of various sustainability development practices in an organization. This approach, however, is optimization-oriented. Furthermore, the resulted outcome from applying such an approach in a specific situation is incomparable across various organizations due to the specific nature of individual organizations and the different priorities of various sustainability development objectives in these organizations.

Munda (2005a, b) presents a multi-criteria analysis approach for measuring organizational sustainability development in a given situation. In considering the multi-dimensional nature of the problem for evaluating and measuring the sustainability development performance of individual organizations, a multi-criteria analysis framework is proposed. To produce an overall ranking of the organizations considered in the evaluation process, the simple additive weighting method (Deng and Yeh, 2006) is adopted based on a pairwise comparison technique (Deng, 1999) for determining the weights of the sustainability indicators from the perspective of stakeholders. The underlying concept of such an approach is simple, and the computation involved is effective. The approach, however, is subject to the perceived importance of the sustainability indicators from the perspective of stakeholders. As a result, the ranking outcomes are not comparable across different situations as various stakeholders often have different perceptions of the importance of the sustainability indicators in the evaluation process.

The discussion above shows that existing approaches for measuring and evaluating sustainability development performance in organizations are not totally satisfactory due to various shortcomings that these approaches suffer from discussed as above. This is in particular the case when an inter-organization comparative study is required for evaluating the relative progress of individual organizations on sustainability development and a widely acceptable ranking outcome is sought after from such a study (Tang and Zhou, 2012). To adequately address these issues, the next section presents an objective approach for measuring and benchmarking organizational sustainability development in a multi-criteria analysis context. Such an approach would lead to an acceptable ranking outcome for all organizations and stakeholders concerned and at the same time pinpoint the areas that each organization can improve in future in order to improve their overall ranking on sustainability development. This is precisely what measuring and benchmarking organizational sustainability development is all about in pursuing organizational sustainability development.

Multi-criteria analysis for benchmarking organizational sustainability development

The performance of sustainability development of individual organizations is often reflected from different perspectives including (a) economy, (b) politics, (c) ecology, and (d) culture (Brunner and Starkl, 2004; Munda, 2004, 2007; Scerri and James, 2010). To adequately assess the relative progress of individual organizations on sustainability development, the use of the multi-criteria analysis methodology (Chen and Hwang, 1992; Yeh *et al.*, 1999; Wibowow and Deng, 2012) is appropriate. This is because the multi-criteria analysis methodology can adequately address the multi-dimensional nature of the inter-organization comparison problem on sustainability development (Deng, 1999; Deng *et al.*, 2000; Munda, 2005; Tang and Zhou, 2012).

Numerous approaches have been developed for solving the general multi-criteria analysis problem (Chen and Hwang, 1992; Deng *et al.*, 2000; Deng, 2009; Wibowow and Deng, 2012). The approaches developed along the multi-attribute utility theory (Hwang and Yoon, 1981; Yeh and Deng, 2004; Deng and Yeh, 2006) are suitable for the inter-organization comparison problem requiring a cardinal preference of alternatives in a given situation (Yeh *et al.*, 1999; Wibowow and Deng, 2012). To facilitate the comparative analysis of the sustainability development performance of individual organizations across various sustainability indicators, the technique for order preference by similarity to ideal solution (TOPSIS) for solving the inter-organization comparison problem on sustainability development is revised (Hwang and Yoon, 1981; Deng *et al.*, 2000; Deng, 2008). The revision of the TOPSIS approach in this situation is because (a) the concept underlying such an approach is rational and comprehensible, (b) the computation involved is simple, (c) the approach is capable of depicting the pursuit of the best performance of an organization at each sustainability indicator in a simple mathematical form, and (d) the approach allows the objective sustainability indicator weights to be incorporated effectively into the comparison process so that an unbiased comparative ranking outcome can be obtained in a given situation (Zeleny, 1982; Deng *et al.*, 2000).

Given a set of organizations (the alternatives: $A = \{A_i, i = 1, 2, \ldots, n\}$) to be compared with respect to a set of sustainability criteria (indicators) (the criteria: $C = \{C_j, j = 1, 2, \ldots, m\}$) in measuring and benchmarking their sustainability development performance, the performance of each organization A_i with respect to each criterion C_j is a crisp value, usually referred as the rating of alternative A_i. It can be obtained from existing sources in the public domain (Munda, 2005a, b). This can lead to the determination of an $n \times m$ performance matrix (the decision matrix; X) for the problem as:

$$X = \left(x_{ij}\right)_{nxm} \tag{1}$$

where x_{ij} ($i = 1, 2, \ldots, n; j = 1, 2, \ldots, m$) is a crisp value indicating the performance of each alternative A_i in regard to each criterion C_j.

Criteria importance is a reflection of the decision maker's subjective preference as well as the objective characteristics of the criteria themselves (Zeleny, 1982; Deng *et al.*, 2000). The subjective preference is usually assigned by the decision maker based on their own experiences, knowledge and perception of the problem via a specific preference elicitation technique (Hwang and Yoon, 1981; Chen and Hwang, 1992; Yeh *et al.*, 1999). This process of assigning the subjective preferences to the criteria is often referred to as subjective weighting. A good review of various subjective weighting methods commonly used in multi-criteria analysis can be found in Hobbs (1978), Schoemaker and Waid (1982), Barron and Barrett (1996), and Yeh *et al.* (1999). The results of these studies show that no single method can guarantee a more accurate result, and the same decision maker may obtain different weights using different methods (Yeh *et al.*, 1999). This is mainly due to the fact that the decision maker cannot always give consistent judgements under different weighting schemes and the weighting process itself is essentially context-dependent (Yeh *et al.*, 1999).

The inconsistency problem in subjective weighting has been well addressed in the literature, reflecting the inherent difficulty of assigning reliable subjective weights in multi-criteria decision making for solving various practical problems. As a result, Fischer (1995), Mareschal (1988), and Triantaphyllou and Sanchez (1997) use a sensitivity analysis approach to give the decision maker the flexibility in assigning criteria weights and help them understand how the weights of criteria affect the decision outcome in the multi-criteria decision making process. Although this approach can reduce the cognitive burden of the decision maker in determining the criteria weights, it may become tedious and difficult to manage when the number of the criteria increases in a specific decision making situation.

Recognizing the fact that criteria weights in a specific situation are context-dependent and task-specific, Ribeiro (1996) presents an interactive run-time method for allowing the decision maker to select the desirable preference elicitation technique in determining the criteria weights. Yeh *et al.* (1999) develop a task-oriented approach that effectively links the criteria weights with the requirements of specific tasks in a given situation for selecting the most suitable alternative. These approaches greatly reduce the burden of the decision maker in the subjective weighting process, therefore achieving a rather consistent weighting outcome in multi-criteria decision making. However, when the problem involves in a group of decision makers with various interests, a consensus on the weights of the criteria may not always be able to achieve (Yeh *et al.*, 2010).

Measuring and benchmarking the performance of sustainability development of individual organizations require the adoption of a commonly accepted basis for carrying out the comparative study (Freudenberg, 2003; Deng, 2008). With the multi-plicity of the problem for measuring and benchmarking the performance of sustainability development of individual organizations in a specific situation, it is difficult for the stakeholders or decision makers with various interests to reach an agreement on the relative importance of the sustainability indicators via a subjective weighting process (Deng *et al.*, 2000; Munda, 2004; Tang and Zhou, 2012). In addition, the sustainability indicators used in the evaluation process may not be totally independent each other as they are all linked and affected by each other to some extent (Lozano and Huisingh, 2011). To effectively address these issues as above, the adoption of an objective weighting process which is carried out independent of the subjective preferences of various decision makers is desirable, in particular when reliable subjective weights of the criteria are not obtainable.

The objective weights of the criteria usually reflect the relative importance of these criteria independent of the subjective preference of individual decision makers (Deng *et al.*, 2000). They are often measured by the average intrinsic information generated by a given set of alternatives through each criterion in a given situation. The determination of the objective criteria weights in a given situation can reflect the nature of the conflicting criteria and consider the inter-dependency between the criteria in a specific situation (Diakoulaki *et al.*, 1995; Deng *et al.*, 2000).

In measuring and benchmarking the performance of sustainability development of individual organizations, the objective weights of the sustainability criteria are determined by the contrast intensity of the organization's performance ratings with respect to each sustainability criterion based on the context-dependent concept of informational importance (Zeleny, 1982). The concept of Shannon's entropy (Shannon and Weaver, 1947) is well suited for measuring the relative contrast intensities of sustainability criteria to represent the average intrinsic information transmitted to the decision maker (Hwang and Yoon, 1981; Zeleny, 1982). It clearly indicates the amount of decision information that each sustainability criterion contains. It is a measure of uncertainty in the information using the probability theory indicating that a broad distribution represents more uncertainty than does a sharply peaked one.

To determine the objective criteria weights by the entropy measure, the decision matrix in (1) needs to be normalized for each criterion C_j ($j=1, 2, \ldots m$) as:

$$p_{ij} = \frac{x_{ij}}{\sum_{p=1}^{n} x_{pj}}, i = 1, 2, ..., n \tag{2}$$

A normalized decision matrix representing the relative performance of the alternatives with respect to each criterion in the multi-criteria analysis problem can then be obtained as:

$$P = \left(p_{ij}\right)_{nxm} \tag{3}$$

The amount of decision information emitted from each criterion C_j ($j=1, 2, \ldots m$) in (3) can thus be measured by the entropy value e_j as:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij}, i = 1, 2, ..., n; j = 1, 2, ..., m \tag{4}$$

where $k = 1/(\ln n)$ is a constant which guarantees $0 \leqslant e_j \leqslant 1$.

The degree of divergence (d_j) of the average intrinsic information contained by each criterion C_j ($j = 1, 2, \ldots m$) can be calculated as:

$$d_j = 1 - e_j \tag{5}$$

d_j represents the inherent contrast intensity of the criterion C_j. The more divergent the performance ratings p_{ij} ($i=1, 2, \ldots, n$) for the criterion C_j, the higher its corresponding d_j, and the more important the criterion C_j for the problem (Zeleny, 1982). This shows that a criterion is less important for a specific problem if all alternatives have similar performance ratings for that criterion (Shipley *et al.*, 1991). If all the performance ratings against a criterion are the same, the criterion can be eliminated in a given situation on which a decision is to be based, because it transmits no information to the decision maker (Zeleny, 1982). This is particularly true for the inter-organizational comparison problem as the overall objective of tackling the problem is (a) to produce an overall ranking of individual organizations on their sustainability development performance and (b) to pinpoint the areas in which individual organizations can improve in future.

The objective weight for each criterion C_j ($j=1, 2, \ldots m$) is thus given by:

$$w_j = \frac{d_j}{\sum_{k=1}^{m} d_k} j = 1, 2, \ldots m \tag{6}$$

After determining the performance ratings of the alternatives and the objective weights of the criteria, the next step is to aggregate them for producing an overall performance index on sustainability development for each organization. This aggregation process starts with the definition of ideal solutions consisting of the positive ideal solution and the negative ideal solution (Hwang and Yoon, 1981; Yeh *et al.*, 2000). The positive (or negative) ideal solution consists of the best (or worst) criteria values attainable from all the alternatives if each criterion takes monotonically increasing or decreasing values in the decision matrix shown as in (1). Following this definition, the positive ideal solution (A^+) and the negative ideal solution (A^-) can be defined respectively by:

$$A^+ = \left(\max_i (p_{i1}),\ \max_i (p_{i2}),\ \ldots,\ \max_i (p_{im})\right) = \left(p_1^+, p_2^+,\ \ldots,\ p_m^+\right)$$

$$i = 1, 2, \ldots, n$$

$$A^- = \left(\min_i (p_{i1}),\ \min_i (p_{i2}),\ \ldots,\ \min_i (p_{im})\right) = \left(p_1^-, p_2^-,\ \ldots,\ p_m^-\right) \tag{7}$$

The overall performance index of an alternative across all criteria is determined by the relative closeness of each alternative to A^+ and A^-. This distance is interrelated with the criteria weights (Zeleny, 1982) and should be incorporated in the distance measurement (Shipley *et al.*, 1991; Yeh *et al.*, 1999). This is because all the alternatives are compared with A^+ and A^-, rather than directly among themselves. In the TOPSIS method, the criteria weights mainly serve as a channel through which the criteria with different performances can be brought together. The decision matrix is weighted by multi-plying each column of the matrix by its associated criteria weight. Thus, the resultant Euclidean distances are not weighted at all, and are often subject to an amorphous interpretation (Deng *et al.*, 2000; Deng, 2008). To avoid this problem, the weighted Euclidean distances instead of the weighted decision matrix required by the technique for order preference by similarity to ideal solution is used in the aggregation process.

From (3) and (7), the weighted Euclidean distances, between A_i and A^+, and between A_i and A^-, are calculated respectively as:

$$d_i^+ = \left[\sum_{j=1}^{m} w_j \left(d_{ij}^+\right)^2\right]^{1/2}; \quad d_i^- = \left[\sum_{j=1}^{m} w_j \left(d_{ij}^-\right)^2\right]^{1/2}, i = 1, 2, \ldots, n \tag{8}$$

where $d_{ij}^+ = p_j^+ - p_{ij}$, $d_{ij}^- = p_{ij} - p_j^-$, $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, m$.

The most preferred alternative should not only have the shortest distance from the positive ideal solution, but also have the longest distance from the negative ideal solution at the same time (Hwang and Yoon, 1981; Chen and Hwang, 1992; Deng *et al.*, 2000; Wibowow and Deng, 2012). Following this principle, an overall performance index for each alternative A_i ($i = 1, 2, \ldots, n$) across all the criteria is thus computed by:

$$P_i = \frac{d_i^-}{d_i^+ + d_i^-}, \ i = 1, 2, \ldots, n \tag{9}$$

The larger the index value, the better the overall performance of the alternative.

An example

The International Data Corporation (IDC) publishes a Worldwide Information Society Index annually as an indication of the relative progress of individual countries worldwide on the progress of the sustainability development of individual countries. The published index is based on four sustainability criteria including (a) information, (b) hardware, (c) social infrastructure, and (d) internet infrastructure. Within this framework, scores are given to each country with respect to each criterion on their respective performance of each country on their sustainability development. An overall ranking of individual countries concerned are determined based on these aggregated scores. Table I shows the performance data of individual countries with respect to the four sustainability development criteria published by IDC in 2003 (IDC, 2002).

To facilitate the inter-country analysis on their sustainability development performance, Table II shows the overall performance rankings of these countries on sustainability development and the rankings of these countries on individual sustainability criteria. It is obvious that the USA has demonstrated the best performance among the countries considered. However it is worth to point out that USA still has the highest overall ranking due to its performance on the criterion of hardware although it does not perform well on the sustainability criteria of information, social infrastructure, and internet infrastructure. This shows that the IDC approach cannot pinpoint the areas in which individual organizations need to improve in order to further strengthen their relative positions on sustainability development.

To provide a commonly acceptable overall ranking for these countries above on their sustainability development performance, the objective approach developed in this paper is used. Following the objective approach developed above, the decision matrix contained in Table I needs to be normalized by (2). Table III shows the result.

The positive ideal solution and the negative ideal solution can then be determined by (7) as:

$A^+ = (0.12, 0.19, 0.12, 0.13)$

$A^- = (0.09, 0.06, 0.07, 0.07)$

Table I.
Performance assessments of countries on individual sustainability criteria

Country	Information (C_1)	Hardware (C_2)	Social infrastructure (C_3)	Internet infrastructure (C_4)
Australia	1,892	797	1,350	2,302
France	1,891	626	1,068	1,504
Germany	2,248	623	1,134	1,902
Italy	2,001	452	885	1,410
New Zealand	1,979	780	1,126	1,790
Singapore	1,953	800	810	2,504
South Korea	2,085	548	1,289	1,674
UK	2,292	782	1,139	2,224
US	2,167	1,362	1,099	2,004
Taiwan	2,602	581	1,257	1,852

Table II.
IDC rankings of individual countries on individual criteria and across all criteria

Country	Information (C_1)	Hardware (C_2)	Social infrastructure (C_3)	Internet infrastructure (C_4)	IDC Overall ranking
Australia	9	3	1	2	3
France	10	6	8	9	9
Germany	3	7	5	5	6
Italy	6	9	9	10	10
New Zealand	7	5	6	7	7
Singapore	8	2	10	1	5
South Korea	5	10	2	8	8
UK	2	4	4	3	2
US	4	1	7	4	1
Taiwan	1	8	3	6	4

Country	Information (C_1)	Hardware (C_2)	Social infrastructure (C_3)	Internet infrastructure (C_4)
Australia	0.09	0.11	0.12	0.12
France	0.09	0.09	0.10	0.08
Germany	0.11	0.08	0.10	0.10
Italy	0.09	0.06	0.08	0.07
New Zealand	0.09	0.11	0.10	0.09
Singapore	0.09	0.11	0.07	0.13
South Korea	0.10	0.07	0.12	0.09
UK	0.11	0.11	0.10	0.12
US	0.10	0.198	0.10	0.10
Taiwan	0.12	0.08	0.11	0.10

Table III. The normalized decision matrix

With the determination of the positive ideal solution and the negative ideal solution, the relative performance of individual organizations with respect to each sustainability criterion can be calculated. This would give all the stakeholders valuable information on their understanding of their relative progress in their endeavours towards the information economy (EIU, 2003; Jaeger, 2003; Torres *et al.*, 2005). It also provides individual countries with useful information with respect to areas that they need improve to catch up on sustainability development worldwide (Gupta and Jana, 2003; Love *et al.*, 2004).

With the use of the objective method for criteria weighting, the relative importance of the four sustainability criteria can be calculated. Table IV shows the criteria weights using the objective method for criteria weighting. To facilitate the comparative study on the ranking outcomes of different countries on their sustainability development between different weighting methods, two additional objective weighting methods including the CRITIC (CRiteria Importance Through Intercriteria Correlation) method (Diakoulaki *et al.*, 1992) and the standard deviation (SD) method (Deng *et al.*, 2000) are used for determining the criteria weights shown as in Table IV as well.

With the use of the objective approach developed as above, the overall performance index for each country across all the sustainability development criteria can be determined. Table V shows the index values and the corresponding rankings of these countries with the use of three sets of objective criteria weights. To facilitate the comparative study, the IDC overall ranking of these organizations and their index values are also included in Table V.

Table V shows that US has the best performance on sustainability development, no matter which methods for criteria weighting are used. This shows that US has excelled in every aspect of sustainability development in this specific evaluation situation. The objective approach, however, does give all the stakeholders confidence in accepting the evaluation outcome as it does not involves any subjective view of the stakeholders in the evaluation process. Table V also shows that rankings of the ten countries with

Objective weighting	Information (C_1)	Hardware (C_2)	Social infrastructure (C_3)	Internet infrastructure (C_4)
EW	0.25	0.27	0.24	0.24
SD	0.14	0.44	0.19	0.23
CRITIC	0.15	0.37	0.24	0.24

Table IV. Criteria weights using the three objective criteria weighting methods respect to their relative performance in sustainability development using the objective criteria weights are different from the rankings resulted from the use of the IDC approach.

A comparative analysis of the ranking outcomes in Table V shows that the rankings resulted from the use of the EW weights and CRITIC are consistent. This may be due to the fact that both objective weighting methods are better in reflecting the relative contrast intensities of the sustainability criteria to represent the average intrinsic information transmitted to the decision maker in the evaluation process. Such a consistent ranking outcomes would further improve the acceptability of the ranking result on the basis of the use of the objective criteria weighting for avoiding the potential bias in the subjective weighting process by the decision maker for addressing the inter-country sustainability development performance comparison problem in benchmarking study. This is in particular the case as the process of determining the criteria weight does not involve in the subjective judgement of the decision maker in the overall performance evaluation process. As a result, the bias of the decision maker in assessing the criteria weights is effectively avoided.

Conclusion

Comparing and evaluating the relative performance of organizations on their sustainability development in an objective manner is of great significance for understanding the relative status of individual organizations on sustainability development (Munda, 2004; Tang and Zhou, 2012). Such a study is often carried out in terms of benchmarking sustainability development for comparing inter-country sustainability development performance in which the performance of individual countries on sustainability development is compared with the best practitioners, leading to the identification of the performance gaps between each country and the best practitioners and the development of fresh approaches in sustainability development for improving the performance of those countries on sustainability development.

To address the problem of measuring and benchmarking sustainability development performance of individual organizations as above, this paper recognizes the multi-dimensional nature of the inter-country comparison problem on sustainability development and proposes an objective approach for effectively solving the problem in a straightforward manner. Such a novel approach in measuring and benchmarking sustainability development performance can address the shortcomings of existing studies in the sustainability development performance evaluation. The proposed objective approach is not only able to provide an objective view of the relative progress of

Table V. Index values of individual countries on sustainability development and their corresponding overall rankings

	EW		CRITIC		SD		IDC	
Country	Value	Ranking	Value	Ranking	Value	Ranking	Value	Ranking
Australia	0.49	2	0.47	2	0.45	2	6,341	3
France	0.22	9	0.21	9	0.21	9	5,089	9
Germany	0.30	7	0.28	7	0.26	7	5,907	6
Italy	0.05	10	0.04	10	0.04	10	4,748	10
New Zealand	0.37	5	0.37	5	0.37	5	5,675	7
Singapore	0.43	4	0.42	4	0.43	3	6,067	5
South Korea	0.27	8	0.25	8	0.22	8	5,596	8
UK	0.45	3	0.43	3	0.42	4	6,437	2
US	0.77	1	0.81	1	0.83	1	6,632	1
Taiwan	0.34	6	0.30	6	0.27	6	6,292	4

those countries concerned in the process of evaluating their relative performance in sustainability development but also pinpoint the areas that these countries can further improve to lift their overall profile worldwide on their sustainability development. Furthermore, the adoption of such an objective approach in measuring and benchmarking sustainability development facilitates the acceptability of an inter-country ranking outcome on sustainability development performance by various stakeholders which is significant in real world situations.

An empirical study on the real data available is presented that shows that the approach is effective in presenting an objective view of individual countries on their relative progress on sustainability development and the resulting comparison results are better acceptable to all the stakeholders involved. As a result, the methodology developed can be used as a decision making tool to support various levels of government and consultancy organizations worldwide in their effort to evaluate the adoption of specific strategies and policies in sustainability development so that effective decisions can be made for actively pursuing sustainability development in individual countries as well as organizations.

There are numerous other approaches in multi-criteria decision making including the outranked based approach, pairwise comparison based approach, and the utility based approach which are widely used for evaluating the relative performance of alternatives with respect to multiple, usually conflicting criteria. With the multi-dimensional nature of the problem of measuring and benchmarking the organizational sustainability development, these approaches have the potential for helping better addressing such a problem in real world setting. This can be part of the future research in this area for actively pursuing effective approaches to measuring and benchmarking the sustainability development performance of individual organizations in the real world.

References

Agger, A. (2010), "Involving citizens in sustainable development: evidence of new forms of participation in the Danish agenda 21 schemes", *Local Environment*, Vol. 15 No. 6, pp. 541-552.

Alaraifi, A., Molla, A. and Deng, H. (2012), "The assimilation of sensor information systems: an empirical investigation in the data centres industry", *International Journal of Business Information Systems*, Vol. 11 No. 3, pp. 283-303.

Alaraifi, A., Molla, A. and Deng, H. (2013), "An exploration of data center information systems", *Journal of Systems and Information Technology*, Vol. 14 No. 4, pp. 353-370.

Atkinson, G. (2000), "Measuring corporate sustainability", *Journal of Environmental Planning and Management*, Vol. 43 No. 2, pp. 235-252.

Bansal, P. and Roth, K. (2000), "Why companies go green: a model of ecological responsiveness", *The Academy of Management Journal*, Vol. 43 No. 4, pp. 717-736.

Barron, F.H. and Barrett, B.E. (1996), "Decision quality using ranked attribute weights", *Management Science*, Vol. 42 No. 11, pp. 1515-1523.

Baumgärtner, S. and Quaas, M. (2010), "What is sustainability economics?", *Ecological Economics*, Vol. 69 No. 3, pp. 445-450.

Bibri, M. (2009), *ICT Design Unsustainability and the Path toward Environmentally Sustainable Technologies*, Blekinge Institute of Technology, Master Thesis, Karlskrona.

Brundtland Commission (1987), *Our Common Future, United Nations World Commission on Environment and Development*, Oxford University Press, Oxford.

Brunner, N. and Starkl, M. (2004), "Decision aid systems for evaluating sustainability: a critical survey", *Environmntal Impact Assessment Review*, Vol. 24 No. 4, pp. 441-469.

Chen, S.J. and Hwang, C.L. (1992), "Fuzzy multiple attribute decision making: methods and applications", Springer-Verlag, New York.

Cherchye, L. and Kuosmanen, T. (2004), "Benchmarking sustainability development: a synthetic meta-index approach", Research Paper No. 2004/28, Would Institute for Development Economic Research, Helsinki.

Costanza, R. and Wainger, L. (1991), *Ecological Economics: Mending the Earth*, North Atlantic Books, Berkeley, CA.

Daly, H.E. and Cobb, J.J. (1990), *For the Common Good: Redirecting the Economy Toward Community, the Environment and a Sustainable Future*, Beacon Press, Boston, MA.

Deng, H. (1999), "Multicriteria analysis with fuzzy pairwise comparison", *International Journal of Approximate Reasoning*, Vol. 21 No. 3, pp. 215-231.

Deng, H. (2008), "Towards objective benchmarking of e-government: an inter-country analysis", *Transformational Government: People, Process and Policy*, Vol. 3 No. 4, pp. 162-176.

Deng, H. (2009), "Developments in fuzzy multicriteria analysis", *Fuzzy Information and Engineering*, Vol. 1, pp. 109-115.

Deng, H. and Yeh, C.H. (2006), "Simulation-based evaluation of defuzzification-based approaches to fuzzy multiattribute decision making", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 36 No. 5, pp. 968-977.

Deng, H., Yeh, C.H. and Willis, R.J. (2000), "Inter-company comparison using modified TOPSIS with objective weights", *Computers and Operations Research*, Vol. 27 No. 10, pp. 963-973.

Diakoulaki, D., Mavrotas, G. and Papayannakis, L. (1992), "A multicriteria approach for evaluating the performance of industrial firms", *Omega*, Vol. 20, pp. 467-474.

Diakoulaki, D., Mavrotas, G. and Papayannakis, L. (1995), "Determining objective weights in multiple criteria problems: the CRITIC method", *Computers and Operations Research*, Vol. 22 No. 7, pp. 763-770.

Donaldson, T. and Preston, L.E. (1995), "The stakeholder theory of the corporation: concepts, evidence, and implications", *The Academy of Management Review*, Vol. 20 No. 1, pp. 65-91.

Dow Jones Sustainability Indexes (2010), "Corporate sustainability", available at: www.sustainability indexes.com/07_htmle/sustainability/corpsustainability.html (accessed 9 October 2010).

Dunphy, D.C., Griffiths, A. and Benn, S. (2003), *Organizational Change for Corporate Sustainability : A Guide for Leaders and Change Agents of the Future*, Routledge, London.

Dyllick, T. and Hockerts, K. (2002), "Beyond the business case for corporate sustainability", *Business Strategy and the Environment*, Vol. 11 No. 2, pp. 130-141.

Ebner, D. and Baumgartner, R.J. (2006), "The relationship between sustainable development and corporate social responsibility", *Proceedings of the Corporate Responsibility Research Conference 2006*, *Dublin, 4th-5th September*.

Economist Intelligence Unit (EIU) (2003), "The 2003 e-readiness rankings", available at: http://graphics.eiu.com/files/ad_pdfs/eReady_2003.pdf (accessed August 10, 2013).

Elkington, J. (1994), "Towards the sustainable corporation: win-win-win business strategies for sustainable development", *California Management Review*, Vol. 36 No. 2, pp. 90-100.

Elkington, J. (1998), "Cannibals with forks: the triple bottom line of 21st century business", Capstone.

Fischer, G.W. (1995), "Range sensitivity of attribute weights in multiattribute value model", *Organizational Behaviour and Human Decision Processes*, Vol. 62 No. 3, pp. 252-266.

Fraser, E.D.G., Dougill, A.J., Mabee, W.E., Reed, M. and McAlpine, P. (2006), "Bottom up and top down: analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management", *Journal of Environmental Management*, Vol. 78 No. 2, pp. 114-127.

Freudenberg, M. (2003), "Composite indicators of country performance: a critical assessment", Working Paper No. 2003/16, STI, Paris.

Gupta, M.P. and Jana, D. (2003), "E-government evaluation: a framework and case study", *Government Information Quarterly*, Vol. 20, pp. 365-387.

Hart, S.L. (1997), "Beyond greening: strategies for a sustainable world", *Harvard Business Review*, Vol. 75 No. 1, pp. 66-77.

Hart, S.L. and Milstein, M.B. (1999), "Global sustainability and the creative destruction of industries", *Sloan Management Review*, Vol. 41 No. 1, pp. 23-33.

Hawken, P. (1993), *The Ecology of Commerce: A Declaration of Sustainability*, HarperCollins, New York, NY.

Hobbs, B.F. (1978), "A comparison of weighting methods in power plant citing", *Decision Sciences*, Vol. 11 No. 4, pp. 725-737.

Hwang, C.L. and Yoon, K.S. (1981), *Multiple Attribute Decision Making: Methods and Applications*, Springer-Verlag, New York, NY.

International Data Corporation (IDC) (2002), *World Information Society Index*, IDC/World Times Survey, available at: www.worldpaper.com/2002/Feb02/isi.jpg (accessed August 10, 2013).

Jaeger, P.T. (2003), "The endless wire: e-government as global phenomenon", *Government Information Quarterly*, Vol. 20, pp. 323-331.

Lo, S.F. and Sheu, H.J. (2007), "Is corporate sustainability a value-increasing strategy for business?", *Corporate Governance: An International Review*, Vol. 15 No. 2, pp. 345-358.

Love, P.E.D., Irani, Z. and Edwards, D.J. (2004), "Industry-centric benchmarking of information technology benefits, costs and risks for small-to-medium sized enterprises in construction", *Automation in Construction*, Vol. 13, pp. 507-524.

Lozano, R. and Huisingh, D. (2011), "Inter-linking issues and dimensions in sustainability reporting", *Journal of Cleaner Production*, Vol. 19 Nos 2/3, pp. 99-107.

Magee, L., Scerri, A., James, P., Thom, J.A., Padgham, L., Hickmott, S., Deng, H. and Cahill, F. (2013), "Reframing social sustainability reporting: toward an engaged approach", *Environment, Development and Sustainability*, Vol. 15 No. 2, pp. 225-243.

Mareschal, B. (1988), "Weight stability intervals in multicriteria decision aid", *European Journal of Operational Research*, Vol. 33 No. 1, pp. 54-64.

Munda, G. (2004), "Social multi-criteria evaluation (SMCE): methodological foundations and operational consequences", *European Journal of Operational Research*, Vol. 158 No. 3, pp. 662-677.

Munda, G. (2005a), "Multi-criteria decision analysis and sustainable development", in Figuera, J., Greco, S. and Ehrgott, M. (Eds), *Multiple – Criteria Decision Analysis. State of Art Surveys*, Springer, New York, NY, pp. 953-986.

Munda, G. (2005b), "Measuring sustainability: a multi-criterion framework", *Environment, Development and Sustainability*, Vol. 7 No. 1, pp. 117-134.

Munda, G. (2007), *Social Multi-Criteria Evaluation*, Springer-Verlag, New York, NY.

Naveh, Z. (1998), "Ecological and cultural landscape restoration and the cultural evolution towards a post-industrial symbiosis between human society and nature", *Restoration Ecology*, Vol. 2 No. 2, pp. 135-43.

Pearce, D.W. and Atkinson, G.D. (1993), "Capital theory and the measurement of sustainable development: an indicator of 'weak' sustainability", *Ecological Economics*, Vol. 8 No. 2, pp. 103-108.

Petrini, M. and Pozzebon, M. (2009), "Managing sustainability with the support of business intelligence: integrating socio-environmental indicators and organisational context", *The Journal of Strategic Information Systems*, Vol. 18 No. 4, pp. 178-191.

Porter, M.E. and van der Linde, C. (1995), "Toward a new conception of the environment-competitiveness relationship", *Journal of Economic Perspectives*, Vol. 9 No. 4, pp. 97-118.

Ribeiro, R.A. (1996), "Fuzzy multiple attribute decision making: a review and new preference elicitation techniques", *Fuzzy Sets and Systems*, Vol. 78 No. 2, pp. 155-181.

Robèrt, K.H., Schmidt-Bleek, B., Aloisi de Larderel, J., Basile, G., Jansen, J.L., Kuehr, R., Price Thomas, P., Suzuki, M., Hawken, P. and Wackernagel, M. (2002), "Strategic sustainable development – selection, design and synergies of applied tools", *Journal of Cleaner Production*, Vol. 10 No. 3, pp. 197-214.

Sahay, A. (2004), "Environmental reporting by Indian corporations", *Corporate Social Responsibility and Environmental Management*, Vol. 11 No. 1, pp. 12-22.

Scerri, A. and James, P. (2010), "Accounting for sustainability: combining qualitative and quantitative research in developing 'indicators' of sustainability", *International Journal of Social Research Methodology*, Vol. 13 No. 1, pp. 41-53.

Schoemaker, P.J.H. and Waid, C.D. (1982), "An experimental comparison of different approaches to determining weights in additive utility models", *Management Science*, Vol. 28 No. 2, pp. 182-196.

Shannon, C.E. and Weaver, W. (1947), *The Mathematical Theory of Communication*, The University of Illinios Press, Urbana, IL.

Shipley, M.F., de Korvin, A. and Obid, R. (1991), "A decision making model for multi-attribute problems incorporating uncertainty and bias measures", *Computers and Operations Research*, Vol. 18 No. 4, pp. 335-342.

Tam, E.K.L. (2002), "Challenges in using environmental indicators for measuring sustainability practices", *Journal of Environmental Engineering and Science*, Vol. 1 No. 6, pp. 417-425.

Tang, C. and Zhou, S. (2012), "Research advance in environmentally and socially sustainable operations", *European Journal of Operational Research*, Vol. 223 No. 3, pp. 585-594.

Torres, L., Pina, V. and Acerete, B. (2005), "E-government developments on delivering public services among EU cities", *Government Information Quarterly*, pp. 217-238.

Triantaphyllou, E. and Sanchez, A. (1997), "A sensitivity analysis approach for some deterministic multi-criteria decision making methods", *Decision Sciences*, Vol. 28 No. 1, pp. 151-194.

United Nations (1992), "Agenda 21", *United Nations Conference on Environment and Development (UNCED)*, UN General Assembly, *Rio de Janeiro*, June 3-14, available at: www.un.org/esa/dsd/agenda21/ (accessed August 12, 2013).

Veleva, V., Hart, M., Greiner, T. and Crumbley, C. (2001), "Indicators of sustainable production", *Journal of Cleaner Production*, Vol. 9 No. 1, pp. 447-452.

Veleva, V., Hart, M., Greiner, T. and Crumbley, C. (2003), "Indicators for measuring environmental sustainability: a case study of the pharmaceutical industry", *Benchmarking: An International Journal*, Vol. 10 No. 2, pp. 107-119.

Vitousek, P., Ehrlich, P., Ehrlish, A. and Matson, P. (1986), "Human appropriation of the products of photosynthesis", *Bioscience*, Vol. 34 No. 6, pp. 368-373.

Wackernagel, M. and Rees, W.E. (1995), *Our Ecological Footprint: Reducing Human Impact on The Earth*, New Society Publishers, Gabriola Island.

Wibowow, S. and Deng, H. (2012), "Intelligent decision support for effectively evaluating and selecting ships under uncertainty in marine transportation", *Expert Systems with Applications*, Vol. 39 No. 8, pp. 6911-6920.

World Commission on Environment and Development (1987), "Our common future", report of the World Commission on Environment and Development, Oxford.

Yeh, C.H. and Deng, H. (2004), "A practical approach to fuzzy utilities comparison in fuzzy multicriteria analysis", *International Journal of Approximate Reasoning*, Vol. 35 No. 2, pp. 179-194.

Yeh, C.H., Deng, H. and Chang, Y.H. (2000), "Fuzzy multicriteria analysis for performance evaluation of bus companies", *European Journal of Operational Research*, Vol. 126 No. 3, pp. 1-15.

Yeh, C.H., Deng, H., Wibowo, S. and Xu, Y. (2010), "Multicriteria group decision for information systems project selection under uncertainty", *International Journal of Fuzzy Systems*, Vol. 12 No. 2, pp. 170-179.

Yeh, C.H., Willis, R.J., Deng, H. and Pan, H. (1999), "Task-oriented weighting in multi-criteria analysis", *European Journal of Operational Research*, Vol. 119 No. 1, pp. 130-146.

Zeleny, M. (1982), *Multiple Criteria Decision Making*, McGraw-Hill, New York, NY.

Further reading

Brucker, K.D. Macharis, C. and Verbeke, A. (2013), "Multi-criteria analysis and the resolution of sustainable development dilemmas: a stakeholder management approach", *European Journal of Operational Research*, Vol. 224 No. 2, pp. 122-131.

Daly, M. and Butler, T. (2009), "Environmental responsibility and green IT: an institutional perspective", *Proceedings of the 17th European Conference on Information Systems, Verona, 8-10 June*.

Global Reporting Initiative (GRI) (2006), *Sustainability Reporting Guidelines*, Global Reporting Initiative (GRI), Boston, MA, available at: www.globalreporting.org/ReportingFramework/ReportingFrameworkDownloads/ (accessed August 10, 2013).

Hussey, D.M., Kirsop, P.L. and Meissen, R.E. (2001), "Global reporting initiative guidelines: an evaluation of sustainable development metrics for industry", *Environmental Quality Management*, Vol. 11 No. 1, pp. 1-20.

Krank, S., Wallbaum, H. and Grêt-Regamey, A. (2010), "Constraints to implementation of sustainability indicator systems in five Asian cities", *Local Environment*, Vol. 15 No. 8, pp. 731-742.

Pearce, D.W. and Turner, R.K. (1990), *Economics of Natural Resources & Environment*, The John Hopkins University Press, Baltimore, MD.

Rydin, Y. (2007), "Indicators as a governmental technology? The lessons of community-based sustainability indicator projects", *Environment and Planning D: Society and Space*, Vol. 25 No. 4, pp. 610-624.

Willis, A. (2003), "The role of the global reporting initiative's sustainability reporting guidelines in the social screening of investments", *Journal of Business Ethics*, Vol. 43 No. 3, pp. 233-237.

Corresponding author
Professor Hepu Deng can be contacted at: hepu.deng@rmit.edu.au

This article has been cited by:

1. Sebastian Brockhaus Weber State University, Ogden, UT, USA Stan Fawcett Weber State University, Ogden, UT, USA Wolfgang Kersten Hamburg University of Technology, Hamburg, Germany Michael Knemeyer The Ohio State University, Columbus, OH, USA . 2016. A framework for benchmarking product sustainability efforts. *Benchmarking: An International Journal* **23**:1, 127-164. [Abstract] [Full Text] [PDF]
2. Jing Zhao, Hepu DengRanking Discrete Multi-attribute Alternatives under Uncertainty 51-55. [CrossRef]
3. Santoso Wibowo, Hepu Deng. 2015. Multi-criteria group decision making for evaluating the performance of e-waste recycling programs under uncertainty. *Waste Management* **40**, 127-135. [CrossRef]