Environment and Development Economics 10: 631–649 © 2005 Cambridge University Press
doi:10.1017/S1355770X05002366 Printed in the United Kingdom

Evaluating projects that are potentially eligible for Clean Development Mechanism (CDM) funding in the South African context: a case study to establish weighting values for sustainable development criteria

ALAN C. BRENT*
Department of Engineering and Technology Management, Room 4–12, Engineering 2, University of Pretoria, Pretoria, 0002, South Africa. Tel: +27 12 420 3929. Fax: +27 12 362 5307. E-mail: alan.brent@up.ac.za

RENAT HEUBERGER
Institute of Environmental Physics, Energy and Climate, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland.

DUMISANI MANZINI
Department of Engineering and Technology Management, University of Pretoria, Pretoria, South Africa.

ABSTRACT. Development projects that are potentially eligible for Clean Development Mechanism (CDM) funding under the Kyoto Protocol, require final approval from the host countries where the projects are to be implemented. The approval requires an evaluation of the positive contribution of the CDM project to sustainable development in the host country. A prototype set of sustainable development criteria is introduced using an evaluation process conducted in South Africa. Weighting values that reflect societal priorities in South Africa are required for these criteria. The paper shows how judgements of industry decision makers and the expenditure trends of the national government (on environmental sub-criteria) can be used to generate a first approximation of such weighting values. The industry judgements are obtained from an Analytical Hierarch Process (AHP) survey. They reflect the perceptions of the automotive supply chain and process industry only, and not other parts of the South African society. A more comprehensive study is required to determine the political and social acceptability of the AHP approach, which should be initiated and managed by the Designated National Authority (DNA) of South Africa.

1. Introduction

With the closure of the World Summit on Sustainable Development in Johannesburg in 2002, there was still much confusion and conflict about

*Corresponding author.

Table 1. *Sustainable development indicators at different levels of influence*

Dimensions	*Global*	*National*	*Local (project)*
Environmental	GHG emissions Biodiversity	Biodiversity Air quality Water quality	Local air quality Local water quality
Economic	GDP GDP/capita	Trade Taxes	Employment
Social	Human Development Index	Employment Poverty reduction	Health Community involvement Capacity development

Source: Huq, 2002.

the translation of sustainable development from a generic concept into more concrete terms. However, many agree that sustainable development is about achieving environmental, economic, and social welfare for present as well as future generations (Azapagic and Perdan, 2000), either at the national and global levels from a government perspective (UN Commission on Sustainable Development, 2001) or at a project level from an industry perspective (Labuschagne *et al*., 2005). In the case of certain developments, stakeholders specifically require that environmental, economic, and social goals must be met across all levels. The Clean Development Mechanism (CDM), which forms part of the Kyoto Protocol of 1997, is such a case. Table 1 identifies certain sustainable development indicators that have been proposed for CDM projects (Huq, 2002).

The purpose of CDM is to assist developing countries (not included in Annex 1 of Article 12 of the Kyoto Protocol) in achieving sustainable development and in contributing to the ultimate objective of the United National Framework Convention on Climate Change, and to assist developed countries (included in Annex 1) in achieving compliance with quantified emission limitation and reduction commitments under Article 3 of the Protocol (United Nations Framework Convention on Climate Change, 2003). CDM specifically aims to lower the overall cost of reducing greenhouse gas (GHG) emissions released into the atmosphere in developing countries by forming a means for international trading of GHG emissions. Annex 1 countries can thereby purchase reduced GHG emissions in non-Annex 1 countries and the funds are allocated to reduce the implementation cost of the CDM-eligible project in the host country. The host country has to give a final approval for each CDM project through its Designated National Authority (DNA). The definition of criteria that lead to an approval or a rejection of a project proposal is the full responsibility of the host country.

In many host countries that intend to participate in the Kyoto Protocol process, investigations are currently underway to develop an appropriate procedure to perform the sustainability assessment for CDM project approval. For example, the MATA-CDM (Multi-Attributive Assessment of CDM Projects) tool has been developed for country-specific sustainability assessments (Sutter, 2003). The approach is based on multi-attributive utility theory (MAUT), whereby the utility of an option in a set of alternatives, which reflects the attractiveness of the option, is measured in order to identify the alternative that performs best (Scholz and Tietje, 2002). From the perspective of the DNA, the alternatives are different eligible CDM project proposals, where a project is characterized by a set of sustainable development criteria ($i = 1, \ldots, i = n$), the utility U of a project P can be calculated using the central equation of MATA-CDM (Sutter, 2003)

$$U(P) = \sum_{i=1}^{n} w_i u_i(c_i(P)) \tag{1}$$

where:

U = the overall utility
P = the CDM project
w_i = weighting value of criterion i
u_i = single utility of criterion i (through defined indicators)
c_i = sustainability criterion i

Such a sustainability assessment procedure must therefore stipulate the sustainable development criteria that are to be considered during the evaluation of a project. It must also consider weighting values for these criteria whereby the priorities of a country are incorporated into the evaluation process (Brent, 2002). This paper aims to determine weighting values (from industry and national government perspectives) as a first approximation for an introduced hierarchical set of sustainable development criteria applicable within the context of South Africa.

2. Sustainable development criteria for CDM projects in the South African context

Sustainable development has been conceptualised as a state of dynamic equilibrium between societal demand for a preferred development and the supply of environmental and economic goods and services needed to meet this demand (Briassoulis, 2001). Although consensus on the objectives and basic principles of sustainable development may be obtained, the details of how to achieve sustainable development or maintain sustainability are difficult to generalize, as this is highly dependent on perceptions in specific social-cultural and political contexts that change over time. This is especially problematic where the sustainability of projects, which form the core of business processes, are evaluated against criteria in the global context (Labuschagne *et al*., 2005a).

A number of current integrated frameworks, which are used to assess sustainability at international, national, local or company levels, have been reviewed to determine relevant aspects (or criteria) that should be considered when assessing industry sustainability (Labuschagne *et al*., 2005b). These frameworks included the Global Reporting Initiative, the United Nation's Commission on Sustainable Development's Framework, the Sustainability Metrics of the Institution of Chemical Engineers, and the Wuppertal Sustainability Indicators. Furthermore, general indicator frameworks have been suggested to evaluate the sustainability of

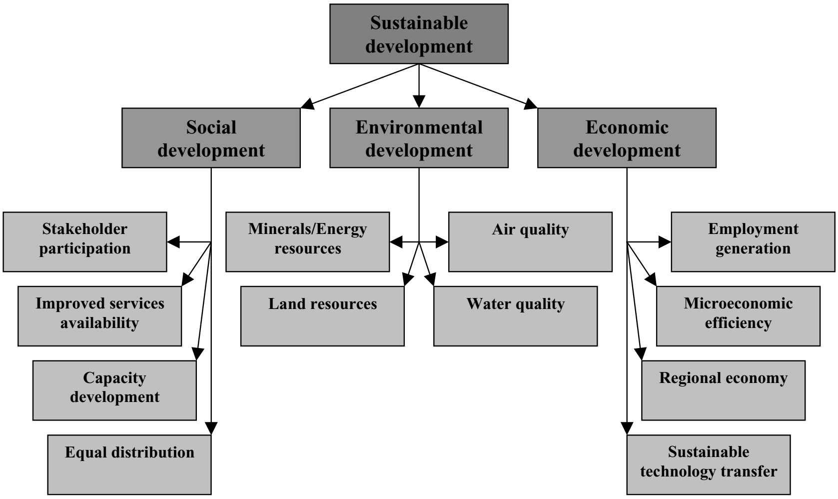

Figure 1. *A hierarchical tree of sustainable development criteria for developing countries (Heuberger, 2003)*

developments in industry (Azapagic and Perdan, 2000). However, these frameworks (and indicators) cannot be used to measure the sustainability of a project directly, i.e. a temporary undertaking that has a specific objective to create a unique product or service and has a definite beginning and end (Kerzner, 2001). The indicators do, nonetheless, show what should be taken into consideration when the environmental, economic, and social performances of a project are measured (Labuschagne, 2003).

In the case of potentially eligible CDM projects, where the country-specific governmental, industrial, and societal preferences should be highlighted in a sustainable development assessment, a hierarchical set of general sustainable development criteria (applicable for all countries) has been proposed (Heuberger, 2003). The hierarchical tree (figure 1) is based on the existing frameworks, although the criteria have been refined in terms of practicability to assess CDM-specific projects.[1]

For development projects in the South African context, further changes to the hierarchical tree have been suggested (CDM Connect, 2002; Brent, 2002), which better reflect the objectives of the South African government and industry. These are the following:

- 'Equal distribution' is replaced with 'social equity and poverty alleviation'; from a company perspective, race and gender equality, training and job creation, etc. form part of the social development responsibility of an industry sector (BMW, 2002; Eskom, 2002; Sasol, 2002).

[1] The modifications to the criteria are largely attributable on an e-conference discussion forum that was held on the internet platform CDM Connect in the period 15 July to 2 August 2002 (CDM Connect, 2002).

Table 2. *Social criteria for development projects in South Africa*

Social criteria	*Description of criteria*
Social equity and poverty alleviation (SE)	• Number of employment opportunities created/ destroyed • Distribution of employment • Types of employment • Categories of people to be employed in terms of gender and racial equity
Improved social services availability (SS)	• Assessment against available policies and plans of national, provincial and local development priorities, e.g. access to sanitation, energy and water supply
Capacity development (CD)	• Training and skills development of project participants and beneficiaries
Stakeholder participation (SP)	• Project developed by and benefiting local communities with meaningful participation • Participation of neighbouring or other African countries

- The four environmental criteria refer to resource groups, i.e. 'mined abiotic resources', 'land resources', 'water resources', and 'air resources'; the South African constitution of 1996 assigns the right of access to these resource groups (South African National Government, 2001). Also, a literature review of environmental checklists, sustainable development indicators, and environmental performance indicators identified the four main environmental groups where industrial projects have potential impacts, i.e. areas of protection (Labuschagne *et al*., 2005b; Brent, 2004).
- 'Regional economy' and 'Employment generation' are replaced with 'Macroeconomic benefits'; although a macroeconomic criterion may not be feasible in CDM evaluations (CDM Connect, 2002), a macroeconomic perspective has been highlighted as extremely important for regional growth, employment and redistribution in South Africa (Mandela, 1996).
- A 'Government investment' criterion is introduced; from the South African government revenue distribution viewpoint, the lesser dependence of a development project on direct national investment support should be emphasized in an assessment (South African National Treasury, 2002).

Based on these changes, a hierarchical set of sustainable development criteria for CDM eligible projects in South Africa is introduced (tables 2–4) for which weighting values are to be established.

3. Methodology to determine weighting values for the sustainable development criteria

Weighting factors for the sub-criteria of the main social, environment, and economic dimensions of sustainable development are primarily

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

Table 3. *Environmental criteria for development projects in South Africa*

Environmental criteria	*Description of criteria*
Air resources (AR)	Regional effects of air pollution: • Human health impacts, e.g. toxicity, respiratory (asthma), smell, noise, etc. • Ecosystem toxicity, i.e. lethal to aquatic and terrestrial plants and animals Global effects of air pollution: • Global warming potential, e.g. CO_2, CH_4, etc. • Stratospheric ozone depletion potential, e.g. CFC-11
Water resources (WR)	• Water availability and use • Human health impacts, e.g. toxic metals and organics, smell, taste, etc. • Ecosystem toxicity, i.e. lethal to aquatic plants and animals • Acidification, e.g. acid rain and acid drainage • Eutrophication, e.g. nitrates and phosphates • Loss of aquatic biodiveristy
Land resources (LR)	• Transformation of land or land use • Loss of topsoil, e.g. erosion • Loss of terrestrial biodiversity • Human health impacts, e.g. toxic metals and organics on soil, etc. • Ecosystem toxicity, i.e. lethal to terrestrial plants and animals • Acidification, e.g. acid rain and acid drainage
Mined abiotic resources (MR)	• Mineral use • Non-renewable fossil fuel use

determined through the analytical hierarchy process (AHP), which is a known multi-attribute weighting method for decision support (Saaty, 1980, 1990; Madu, 1994). The AHP has been used before for the purposes of weighing criteria and indicators for sustainable development in certain industry sectors (Mendoza and Prabhu, 2000; Mendoza and Prabhu, 2003) and for solving complex decision-making problems in various disciplines, e.g. public policy (Kurtilla *et al.*, 2000), strategic planning (Bititci *et al.*, 2001), viability determination (Alidi, 1996), forecasting (Carmone *et al.*, 1997), and project management (Kamal and Al-Subhi Al-Harbi, 2001).

3.1. The AHP methodology

The AHP model is based on a pair-wise weighting approach (Madu and Georgantzas, 1991), whereby the criteria in tables 2–4 are compared with each other to establish each criterion contribution (priority vector) to the objectives, i.e. to maximize the environmental, economic, and social performances of a CDM project.

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

Table 4. *Economic criteria for development projects in South Africa*

Economic criteria	*Description of criteria*
Macroeconomic benefits (ME)	• Project contributes to foreign currency savings, i.e. decrease in forex requirements • Project increases the value generated in a region, and especially export potential • Project decreases poverty in a region, i.e. employment creation
Microeconomic benefits (μE)	• Project increases the return on investment for investors
Government investment (GI)	• Reduction in public sector (local, provincial and national) investment due for a project
Technology transfer and development (TT)	• New technologies to be used in the project, from international or local sources • Technological skills to be transferred and future self reliance of the project • Previous successful application of the technology • Appropriateness of the technology for South Africa • Project provides demonstration and replication potential

A pair-wise comparison matrix (A) is assigned for each of the environmental, economic, and social dimensions of sustainable development, which is of the fourth order, i.e. four criteria are compared for each dimension. The pair-wise comparison matrix consists of elements (a_{ij}). Each element represents the value when criterion i is compared with criterion j. A fundamental 1 to 9 point scale has been introduced for the pair-wise comparisons (Saaty, 1980). Other proposals involve logarithms, geometric powers, and negative numbers (Bodin and Gass, 2003). However, since the precise format of the scale is immaterial, a 1 to 9 point scale is adequate of this study.

The priority vector ($\omega_i, i = 1, \ldots, 4$) is obtained by solving the eigenvector problem (Aguarón and Moreno-Jiménez, 2003). As is stated above, the priority vector is representative of the criterion contribution in the AHP model. The principal eigenvalue is denoted by the symbol $\lambda_{\max}$ and its relation to the pair-wise comparison matrix is illustrated through the following equation

$$\mathrm{A}\omega = \lambda_{\max}\omega \sum_{i=1}^{4} \omega_i = 1 \tag{2}$$

The inconsistencies of the judgments (or pair-wise comparisons) are measured by means of a consistency index (CI) (Aguarón and Moreno-Jiménez, 2003). If the reciprocal comparison matrix is consistent then $\lambda_{\max} = 4$, and $\mathrm{CI} = 0$. The relationship between $\lambda_{\max}$, the order of the

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

comparison matrix (4) and CI is shown in the following equation

$$CI = \frac{\lambda_{max} - 4}{3} \tag{3}$$

A normalization measure is further proposed (Saaty, 1980), referred to as the consistency ratio (CR), in order to overcome the order dependency of CI. A CR of 1.0 indicates that the pair-wise comparison matrix is totally random and thus constitutes a low precision (Aguarón and Moreno-Jiménez, 2003). A CR of less than 0.1 is generally acceptable (Saaty, 1980). For a comparison matrix of the fourth order, a CR of 0.08 is more acceptable (Aguarón and Moreno-Jiménez, 2003). The CR is calculated by dividing the CI by the random (consistency) index (RI) for *n*-order matrices. RI values have been calculated and published in the original AHP methodology documentation (Saaty, 1980).

If the CR is greater than 0.08, a decision maker should consider the re-evaluation of the criteria (in the specific sustainable development dimension). However, the practice of adjusting the comparisons to achieve a consistency ratio of 0 is not advised (Bodin and Gass, 2003) since this would inherently bias toward one criterion in a pair-wise comparison. A CR greater than 0.08 may be accepted if the comparisons are considered fair. A sensitivity analysis is then advisable to establish the impact of the inconsistency.

3.2. Advantages and disadvantages of applying the AHP methodology

From an analytical viewpoint, the AHP produces a larger spread of weights compared with other weighting methods and has some unique modelling features for hierarchy trees (Quaddus and Siddique, 2001). However, some researchers criticize the AHP methodology as lacking a firm theoretical basis, although its wide application is proof that AHP is a usable decision-making tool (Kamal and Al-Subhi Al-Harbi, 2001). Some of the criticisms regarding the AHP are:

- Decision makers may be biased towards certain criteria (or objects). It is therefore essential that a representative sample is used and that the results are reported as characteristic of the specific kind of decision maker that has been chosen. Where a group of decision makers are used, the geometric mean is the representative average of the group, as the standard average does not produce the proper reciprocal (Bodin and Gass, 2003).
- Rank reversal is possible (Zahir, 1999; Millet and Saaty, 2000; Lipovetsky and Conkin, 2002). Rank reversal occurs if an irrelevant alternative is added or removed from the comparisons. This is problematic since a tenet of (revealed preference) utility theory is that a non-optimal alternative cannot become optimal if alternatives are added or deleted. Rank reversal could also occur if an error is made in the evaluation of the pair-wise comparisons (Lipovetsky and Conkin, 2002). In the case of this study, there is no opportunity to add new criteria, and it is therefore only essential to perform the pair-wise comparisons correctly.
- AHP was designed for a maximum of ten objects, i.e. the RI values, etc. were only calculated for up to ten objects in a matrix. Although

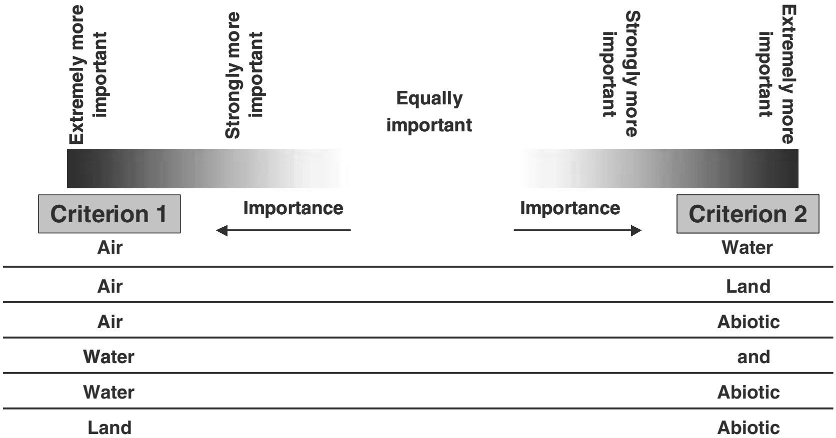

Figure 2. *Integer values are provided for representatives of different sector to indicate the preference between two sub-criteria (environmental criteria)*

some researchers have formulated methodologies for larger matrices, it becomes impractical to work with them, since the number of comparisons increases substantially with the size of the hierarchy (Carmone *et al.*, 1997). The comparisons that are needed to pollinate the hierarchy are proportionate to the matrix size (n) by $(n(n-1)/2)$. A large number of comparisons could therefore lead to information overload and cause errors in judgements. However, in this study only four criteria (or objects) are compared for each dimension.

From section 3.1, participants of a workshop or survey are requested to compare the importance of two attributes or sub-criteria at a time, i.e. which of the two criteria is more important, and how much more important. The participants indicate the strength of their preferences by using integers from 1 to 9 (Saaty, 1980, 1990) as is shown in figure 2 for the environmental sub-criteria. As there are four sub-criteria in each main criterion, six comparisons are required to determine a weighting factor for each of the sub-criteria through the AHP method. With other weighting methods, such as direct weighting methods, the participants compare and weight all four of the sub-criteria simultaneously (Pöyhönen and Hämäläinen, 2001). Although more comparisons are required with the AHP, inconsistencies in the preferences of the participants can be checked (Madu and Georgantzas, 1991).

A previous study in South Africa compared the outcome of the AHP and direct weighting approaches, where a straight interface between the researcher and the participants was possible through workshops (Heuberger, 2003). The research showed that, while both weighting procedures generate similar results, South African participants had less difficulty comprehending the comparisons required by the AHP method. For this reason it was used to establish the weighting values for the environmental, economic, and social sub-criteria of tables 2–4.

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

3.3. Application of the AHP approach to establish weighting values from the perspective of the South African industry

Weighting values of the social, environmental, and economic sub-criteria are established separately in two South African manufacturing industry sectors, as defined by the Standard Industry Classification (Statistics South Africa, 1993): the automobile manufacturing sector and process industries in the automotive value chain. These manufacturing sectors are introducing sustainable development aspects in company decision-making processes (BMW, 2002; Sasol, 2002) and are evaluating projects that are potentially eligible for CDM funding. The weighting values must reflect the importance of the sub-criteria from a project management perspective in industry. Two types of industry participants were subsequently chosen to circulate an AHP survey to that directly control projects (and related budgets) in the specific sectors:

- Managing Directors of South African companies in the automotive supply chain, representing first, second, and third tier suppliers (National Association of Automotive Components and Allied Manufacturers, 2002). Forty-three companies participated in the survey (representing approximately one-quarter of the listed automotive supply industry in South Africa), with acceptable consistency indices and ratios for all pair-wise comparisons.
- Financial Directors of organizations or companies, primarily in the process-related manufacturing industry sector of South Africa, which are listed in the company database of PricewaterhouseCoopers South Africa. Thirteen companies participated in the survey with acceptable consistency indices and ratios for all pair-wise comparisons.

The pair-wise comparisons of the AHP were translated into relative weights using the matrix eigenvalue approach (Saaty and Hu, 1998) described in section 3.1. Web-HIPRE is a free internet interface that allows the user to process AHP models and was used for this translation (Web-HIPRE, 2001). This process generated sub-criteria relative weights for each participant in the survey. These relative weights add up to a total value of 1 for the main social, environment, and economy criteria separately. The industry survey did not include a relative weighting option to compare the three main criteria (social, environmental, and economic development). As a first approximation it is assumed that each of the three main criteria was weighted equally in terms of sustainable development from an industry perspective (UNEP, 2002).

Commonly used group decision-making techniques, such as the Delphi method or nominal group technique, have been used together with the AHP to obtain consensus amongst participants (Madu, 1994; Mendoza and Prabhu, 2000, 2003). However, there was no direct interaction with the industry participants as a group throughout the study (nominal group technique) and multiple survey interactions were not possible (Delphi method) due to the unavailability of the participants; these techniques were therefore not used.

Two techniques are commonly used to aggregate and group the individual judgements obtained from the AHP surveys (Forman and Peniwati, 1998):

- Aggregation of individual judgements (AIJ), whereby the judgements (pair-wise comparisons) are combined before translation to relative weights. The geometric mean of the selected integers (by the participants) for each comparison is obtained and the relative weights calculated through the formula of section 3.1.
- Aggregation of individual priorities (AIP), whereby all individual judgments are first translated to relative weights and then combined. Relative weights are calculated for the criteria through the formula of section 3.1 and the judgments of each participant and the geometric mean values calculated of the spread of relative weights.

It has been argued that the choice of combination method depends on whether the group is assumed to act as a unit or as separate individuals (Forman and Peniwati, 1998). Individual identities, such as the individual levels of inconsistency, are lost with AIJ. Although the circulated survey does represent the response from two specific industry sectors, the groups are not homogenous as it consists of individuals with respective values. AIP is consequently the more appropriate combination method.

3.4. Environmental sub-criteria weighting values

The weighting values of the sub-criteria of the main environment criterion are further evaluated using the priorities of the South African national government. In this case, the expenditure trends of the national government on air, water, land, and mined abiotic resources in the annual budget are considered. Table 5 shows the allocation routes for funding in terms of the four resource groups. Of the annual national budget that is allocated for environmental issues, the fractions that are distributed to the four sub-criteria determine the relative priorities or weights of the sub-criteria.

In the 2002/2003 financial year, 2 per cent of the total annual budget of the national government (R287.9 billion or £19.7 billion at the end of January 2003) has been allocated to environmental issues (South African National Treasury, 2002). This equals a total of R6,625 million (or approximately 1 billion US$) with the following distribution to the four environmental resource groups:

- Air resources – R252 million (4%)
- Water resources – R3,512 million (53%)
- Land resources – R1,118 million (17%)
- Mined abiotic resources – R1,743 million (26%)

These values do not include the funds that have been dispersed from the national budget to provincial and local governments, where the authorities would have individual priorities in terms of addressing provincial and local environmental issues. Also, these budgets are most probably not applied in the same manner to address the protection of the environmental resource groups separately and much of the actual costs may be borne, for

Table 5. *Government directorates and programmes allocated to environmental issues for the 2002/2003 financial year*

Departments	*Directorates and sub-programmes*	*Expenditure allocation*[a]
Environmental Affairs and Tourism	Environmental planning and coordination	Air, water and land resources R121,639,407.66
	Marine and coastal management	Water resources R269,824,298.47
	Tourism	Not applicable
	Environmental quality and protection	
	• Air quality management	Air resources R3,293,855.70
	• Chemical and hazardous waste management	Air, water and land resources R4,751,791.83
	• Waste management	Air, water and land resources R6,533,713.77
	• Climate change and ozone layer protection	Air resources R4,670,795.38
	• Environmental resource economics	Air, water and land resources R820,764.04
	• Financial assistance (poverty relief projects)	Not applicable
	• Contribution to SA Weather Service	Air resources R84,590,534.26
	Biodiversity and heritage	Water and land resources R267,294,607.07
	Auxiliary and associated services	Air, water and land resources R24,423,230.63
Minerals and Energy	Promotion of mine safety and health	Not applicable
	Mineral development	Mined abiotic resources R97,590,790.41
	Energy management	Mined abiotic resources R1,023,019,267.88
	Associated services	Mined abiotic resources R622,184,492.46
Land Affairs	Surveys and mapping	Land resources R61,884,712.38
	Cadastral surveys	Not applicable
	Restitution	Not applicable
	Land reform	Not applicable
	Spatial planning and information	Land resources R15,204,130.60
	Auxiliary and associated services	Not applicable

Table 5. *(continued)*

Departments	*Directorates and sub-programmes*	*Expenditure allocation*[a]
Water Affairs and Forestry	Water resource assessment	Water resources R98,333,556.17
	Integrated water resource planning	Water resources R54,931,475.13
	Water resource development	Water and land resources R258,359,072.76
	Integrated water resource management	
	• Water quality management	Water and land resources R24,066,981.09
	• Catchments management	Water resources R6,449,792.00
	• Working with water	Water resources R12,510,835.29
	• Water utilization	Water resources R40,960,367.36
	• Water conservation	Water resources R16,343,553.85
	Regional implementation	Water resources R2,575,006,052.08
	Water services	Water resources R74,580,701.43
	Forestry	Land resources R396,966,612.84
Agriculture	Farmer support and development	Not applicable
	Agricultural trade and business development	Not applicable
	Agricultural research and economic analysis	Not applicable
	Agricultural production	Not applicable
	Sustainable resource management and use	
	• Water use and irrigation development	Water resources R61,606,154.51
	• Scientific research and development	Water and land resources R865,268.05
	• Land use and soil management	Land resources R76,020,310.65
	• Agricultural Research Commission	Air, water and land resources R319,884,014.41
	• Others	Not applicable
	National agricultural regulatory services	Not applicable
	Agricultural communication, planning and evaluation	Not applicable

Notes: [a] 1 US$ is equal to approximately 6.50 South African Rand (R).

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

Table 6. *The Kolmogorov–Smirnoff test for normality*

Sustainable development criteria	*Managing Director (automotive sector) D Max for n = 43*	*Financial Directors (process industries) D Max for n = 13*
Social equity and poverty alleviation	0.136	0.204
Improved social services availability	0.166	0.139
Capacity development	0.188	0.157
Stakeholder participation	0.167	0.191
Air resources	0.088	0.159
Water resources	0.149	0.304
Land resources	0.114	0.227
Mined abiotic resources	0.198	0.240
Macroeconomic stability	0.149	0.235
Microeconomic stability	0.131	0.230
Government investment	0.175	0.301
Technology transfer and development	0.113	0.204

Note: H_0: The weights generated follow the normal distribution.
H_1: The weights do not follow the normal distribution.
$D_{.05,n=43} = 0.207$.
$D_{.05,n=13} = 0.377$.

example, by the private sector. However, these values are assumed to be an indication of the (environmental) priorities of the national government, which can be compared with the perspectives of the manufacturing industry sectors.

4. Weighting value results for the South African sustainable development criteria

The survey and AHP procedure makes two major assumptions: that the sample obtained from the industry sectors is random, and the weights assigned by the participants are normally distributed (Madu, 1994). As the survey was circulated throughout the industry sectors, it is believed that the responses are representative of the industry sectors at the decision-making level and the assumption of random sampling is discarded. In terms of the normality, the Kolmogorov–Smirnoff test is conducted on the obtained weights from the participants (Daniel, 1990). Table 6 shows that at a level of significance of 0.05, the obtained weights follow a normal distribution.

With respect to the environmental sub-criteria, the relative weighting values as determined from the AHP survey in the two industry sectors and the national expenditure trends are illustrated in figures 3 and 4. Mean values for the sustainable development criteria are obtained from the AIP combination method results of the two industry groups (Forman and Peniwati, 1998). Table 7 summarizes the average weighting values with a 95 per cent confidence level.

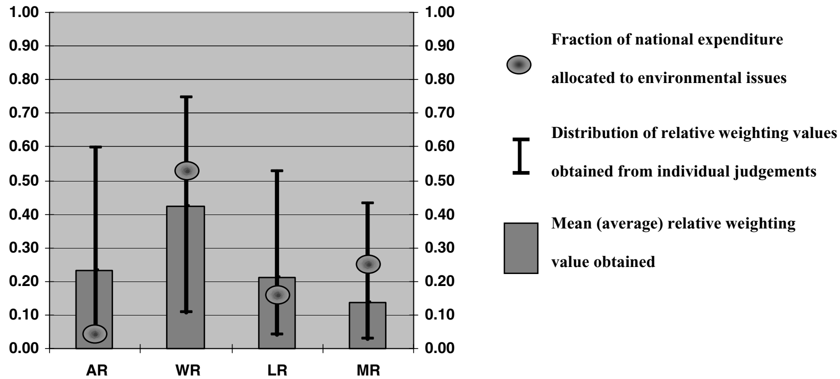

Figure 3. *AHP survey and national expenditure results for the environmental sub-criteria (Managing Directors in the automotive supply chain)*

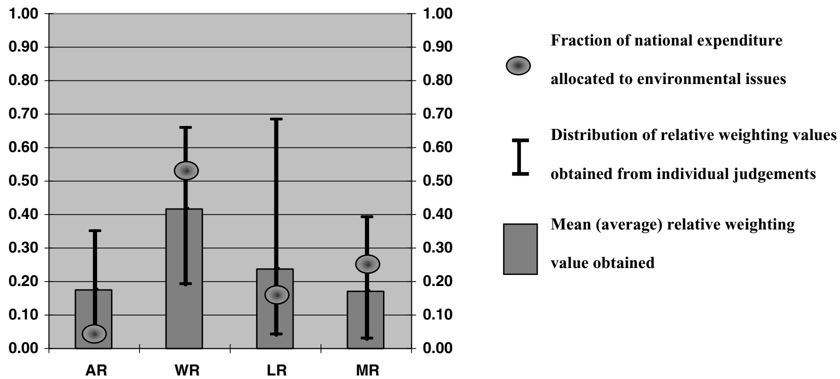

Figure 4. *AHP survey and national expenditure results for the environmental sub-criteria (Financial Directors in the process manufacturing industry)*

4.1. Relative importance of the main sustainable development criteria

The social, environmental, and economic criteria are assumed to be of equal importance from a future industry development perspective. However, South African national government priorities indicate that environmental issues are probably considered of lesser importance (only 2 per cent of the annual budget). Separate weighting values for the main sustainable development criteria should consequently be determined as well. Although a thorough evaluation across all sectors of society is possible, it is expected that individual opinion will vary considerably. The actual application of the subjective weighting values would dictate the importance of the main sustainable development criteria, that is the priorities of the decision makers.

4.2. Relative importance of the social, environmental and economic sub-criteria

The results indicate that 'capacity development' (as defined in table 2) is the most important social sub-criterion from an industry perspective in South

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

Table 7. *Mean values of the AIP combination methods of the relative weighting values obtained from the two manufacturing industry sectors*

Sustainable development criteria	*Mean weighting value*[a]	*95% confidence interval values*
Social equity and poverty alleviation	**0.227**	0.168 to 0.286
Improved social services availability	**0.194**	0.151 to 0.237
Capacity development	**0.387**	0.323 to 0.451
Stakeholder participation	**0.187**	0.147 to 0.228
Air resources	**0.202**	0.165 to 0.239
Water resources	**0.420**	0.371 to 0.468
Land resources	**0.224**	0.189 to 0.259
Mined abiotic resources	**0.154**	0.119 to 0.189
Macroeconomic stability	**0.336**	0.287 to 0.385
Microeconomic stability	**0.235**	0.190 to 0.280
Government investment	**0.140**	0.109 to 0.171
Technology transfer and development	**0.289**	0.234 to 0.344

Note: [a] The mean weighting values for each sustainable development dimension add up to 1.

Africa. The remainder three sub-criteria are of roughly equal importance, although the 'social equity and poverty alleviation' criterion appears to be slightly more important for sustainable development.

Both industry and national government perspectives highlight 'water resources' (as defined in table 3) as the most important environmental sub-criterion. Industry opinion shows that the 'air resources' and 'land resources' sub-criteria are roughly equal, with 'mined abiotic resources' most probably the least important sub-criterion. However, the priorities of the national government indicate that 'mined abiotic resources' are of more importance, albeit to a small degree, compared with 'land resources'. Very little emphasis is placed on 'air resources' at national government level.

The 'macroeconomic benefits' sub-criterion (defined in table 4) is emphasized as the most important for the economic dimensions of sustainable development, especially if employment generation is considered as part of this criterion. The 'government investment' sub-criterion is almost certainly of the least importance.

5. Conclusions

The judgements of representatives from two manufacturing industry sectors have been used to determine relative weighting values of a hierarchical set of sustainable development criteria with the Analytical Hierarchy Process (AHP). The results indicate a normal distribution of the relative weights from the two industry sectors, and mean weighting values have subsequently been determined from an industry perspective (table 7). However, the values are not necessarily representative of individual opinions in government departments, non-government organizations, academia, and businesses not included in the manufacturing sectors. Furthermore, it has also been suggested before that, in some cases, thresholds should be introduced (Heuberger, 2003). The approach entails that projects must contribute positively to certain criteria before they are further considered, which promotes the inclusion of other criteria in a sustainable development assessment of projects.

5.1. Further work required

It is required to obtain the perceptions of the other parts of the South African society, e.g. government departments, non-government organizations, academia, and businesses not included in the two specific manufacturing sectors. Thereby, the political and social acceptability of the AHP approach can be determined. For such a comprehensive analysis a workshop is proposed with representatives of the different parts of society, which are nominated by the Designated National Authority (DNA) as stipulated by the Kyoto Protocol. During the workshop, group decision-making techniques together with the AHP approach can be used to obtain weighting values that are representative for South Africa. It can also be established if certain sustainable development criteria should be considered as thresholds from the perspectives of South African society.

Actual CDM project evaluations are also required to assess the practicality of using the AHP approach and subsequent weighting values.

Acknowledgements

The authors would like to express their gratitude to the Global Risk Management Solutions group, and especially Mrs Harmke Immink, of PricewaterhouseCoopers for their assistance and support with compiling, printing, and distributing the survey questionnaire. The cooperation of industry representatives is also appreciated. Without the participation of these individuals the data would not have been adequate for analysis purposes.

References

Aguarón, J. and J.M. Moreno-Jiménez (2003), 'The geometric consistency index: approximated thresholds', *European Journal of Operational Research* **147**: 137–145.

Alidi, A.S. (1996), 'Use of the analytical hierarchy process to measure the initial viability of industrial projects', *International Journal of Project Management* **14**: 205–208.

Azapagic, A. and S. Perdan (2000), 'Indicator of sustainable development for industry: a general framework', *Trans IchemE* **78**: 243–261.

Bititci, U.S., P. Suwignjo, and A.S. Carrie (2001), 'Strategy management through quantitative modelling of performance measurement systems', *International Journal of Production Economics* **69**: 15–22.

BMW (2002), Sustainable value report 2001/2002, Annual report 2001, http://www.bmwgroup.com, accessed on 22 October 2003.

Bodin, L. and S.I. Gass (2003), 'On teaching the analytic hierarchy process', *Computers and Operations Research* **30**: 1487–1498.

Brent, A.C. (2002), 'A life cycle approach to CDM projects: decision analysis procedure for sustainable development criteria', Presentation at a national CDM workshop of the South African Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

https://doi.org/10.1017/S1355770X05002366 Published online by Cambridge University Press

Brent, A.C. (2004), 'A life cycle impact assessment procedure with resource groups as areas of protection', *International Journal of Life Cycle Assessment* **9**: 172–179.

Briassoulis, H. (2001), 'Sustainable development and its indicators: through a (planner's) glass darkly', *Journal of Environmental Planning and Management* **44**: 409–427.

Carmone, F.J. Jr., A. Kara, and S.H. Zanakis (1997), 'A Monte Carlo investigation of incomplete pairwise comparison matrices in AHP', *European Journal of Operational Research* **102**: 538–553.

CDM Connect (2002), 'Assessment of SD', e-conference, http://www.cdm-connect.org, accessed on 22 October 2003.

Daniel, W.W. (1990), *Applied Nonparametric Statistics*, Boston: PWS-KENT Publishing Company.

Eskom (2002), 'Embracing sustainable development', Annual report 2001, http://www.eskom.co.za/annreport02/home.htm, accessed on 22 October 2003.

Forman, E. and K. Peniwati (1998), 'Aggregating individual judgments and priorities with the analytic hierarchy process', *European Journal of Operational Research* **108**: 165–169.

Heuberger, R. (2003), 'CDM projects under the Kyoto Protocol of the UNFCCC: a methodology for sustainable development assessment and an application in South Africa', Masters thesis, Institute of Environmental Physics, Energy & Climate, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland.

Huq, S. (2002), 'Applying sustainable development criteria to CDM projects: PCF experience', Prototype Carbon Fund report, World Bank, Washington DC, USA, pp. 1–22.

Kamal M. and K.M. Al-Subhi Al-Harbi (2001), 'Application of the AHP in project management', *International Journal of Project Management* **19**: 19–27.

Kerzner, H. (2001), *Project Management: A Systems Approach to Planning, Scheduling and Controlling*, New York: John Wiley & Sons.

Kurttila, M., M. Pesonen, J. Kangas, and M. Kajanus (2000), 'Utilizing the analytic hierarchy process (AHP) in SWOT analysis – a hybrid method and its application to a forest-certification case', *Forest Policy and Economics* **1**: 41–52.

Labuschagne, C. (2003), 'Sustainable project life cycle management', Master thesis, Department of Industrial and Systems Engineering, University of Pretoria, Pretoria, South Africa.

Labuschagne, C., A.C. Brent, and S. Claasens (2005a), 'Environmental and social impact considerations for sustainable project Life Cycle Management in the process industry', *Corporate Social Responsibility and Environmental Management* **12**: 38–54.

Labuschagne, C., A.C. Brent, and P.G. van Erck (2005b), 'Assessing the sustainability performances of industries', *Journal of Cleaner Production* **13**: 373–385.

Lipovetsky, S. and Conkin, W.M. (2002), 'Robust estimation of priorities in the AHP', *European Journal of Operational Research* **137**: 110–122.

Madu, C.N. (1994), 'A quality confidence procedure for GDSS application in multicriteria decision making', *IIE Transactions* **26**: 31–39.

Madu, C.N. and N.C. Georgantzas (1991), 'Strategic thrust of manufacturing automation decisions: a conceptual framework', *IIE Transactions* **23**: 128–148.

Mandela, N. (1996), 'Statement by President Nelson Mandela on the launch of the macroeconomic strategy', Issued by the Office of the President, http://www.polity.org.za/html/govdocs/speeches/1996/index.html, accessed on 22 October 2003.

Mendoza, G.A. and R. Prabhu,(2000), 'Development of methodology for selecting criteria and indicators for sustainable forest management: a case study on participatory assessment', *Environmental Management* **26**: 659–673.

Mendoza, G.A. and R. Prabhu (2003), 'Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management', *Forest Ecology and Management* **172**: 329–343.
Millet, I. and T.L. Saaty (2000), 'On the relativity of relative measures – accommodating both rank preservation and rank reversals in the AHP', *European Journal of Operational Research* **121**: 205–212.
National Association of Automotive Components and Allied Manufacturers (2003), 'Naacam membership database and product category list', http://www.naacam.co.za/, accessed on 22 October 2003.
Pöyhönen, M. and R.P. Hämäläinen (2001), 'On the convergence of multiattribute weighting methods', *European Journal of Operational Research* **129**: 569–585.
Quaddus, M.A. and M.A.B. Siddique (2001), 'Modelling sustainable development planning: a multicriteria decision conferencing approach', *Environment International* **27**: 89–95.
Saaty, T.L. (1980), *The Analytic Hierarchy Process*, New York: McCraw-Hill.
Saaty, T.L. (1990), *Multicriteria Decision Making: The Analytic Hierarchy Process*, Pittsburgh: RWS Publications.
Saaty, T.L. and G. Hu (1998), 'Ranking by eigenvector versus other methods in the analytic hierarchy process', *Applied Mathematical Letters* **11**: 121–125.
Sasol (2002), 'Embracing sustainable development', Company policy report, http://www.sasol.com, accessed on 22 October 2003.
Scholz, R.W. and O. Tietje (2002), *Embeded Case Study Methods: Integrating Quantitative and Qualitative Knowledge*, Sage Publications.
South African National Government (2001), 'Constitutional matters', http://www.polity.org.za/html/govdocs/constitution/, accessed on 22 October 2003.
South African National Treasury (2002), 'Budget 2002 – national medium term expenditure estimates', Division of Corporate Services, http://www.treasury.gov.za/documents/budget/2002/ene/default.htm, accessed on 22 October 2003.
Statistics South Africa (1993), 'Standard Industrial Classification of all economic activities (SIC)', Fifth Edition, http://www.statssa.gov.za/Staticpages/Codelists/SIC.htm, accessed on 22 October 2003.
Sutter, C. (2003), 'Sustainability assessment of energy related projects under the clean development mechanism of the Kyoto Protocol', A dissertation submitted to the Swiss Federal Institute of Technology, Zurich, Switzerland.
United Nations Commission on Sustainable Development (2001), 'Indicators of sustainable development: guidelines and methodologies', http://www.un.org/esa/sustdev/isd.htm, accessed on 22 October 2003.
United Nations Environmental Programme (UNEP) (2002), *Industry as a Partner for Sustainable Development: Compilation of Executive Summaries*, Beacon Press.
United Nations Framework Convention on Climate Change (2003), 'Clean development mechanism', http://cdm.unfccc.int/, accessed on 22 October 2003.
Web-HIPRE (2001), 'Global decision support', Systems Analysis Laboratory, Helsinki University of Technology, http://www.hipre.hut.fi/WebHipre/, accessed on 22 October 2003.
Zahir, S. (1999), 'Geometry of decision making and the vector space formulation of the analytic hierarchy process', *European Journal of Operational Research* **112**: 373–396.