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Sustainability indicators: using the Process Analysis Method to select indicators for assessing production operations

Aidil Chee Tahir and Richard C Darton*
Department of Engineering Science, University of Oxford, Parks Road
Oxford OX1 3PJ, United Kingdom,
richard.darton@eng.ox.ac.uk

Assessing the sustainability impact of a production operation is important for guiding actions towards improving performance. This assessment can be conveniently made by using a set of indicators, but choice of which indicators to select is not straightforward. Here we describe the Process Analysis Method in which the indicator set is designed from a detailed consideration of the production operation. The indicators characterise the impacts of the operation on the capital residing in the three domains: the environment, the economy and the domain of human/social capital. From an analysis based on Brundtland's definition of sustainable development, it is found that these impacts are related to two business perspectives: the resource efficiency**,** and the fairness with which benefits and disbenefits are distributed amongst stakeholders. The Process Analysis Method provides a set of sustainability indicators and metrics tailored to the particular operation, in the context of its business environment. This set will be similar for similar production processes, facilitating comparison and benchmarking. Also, the value of a particular indicator can be traced back through the analysis to a particular activity, which is especially helpful in guiding remedial action, since *cause* is linked to *effect* by the method.

1. Introduction

Publication of the influential report of Brundtland (1987) and the discussion of sustainable development which followed have put businesses under pressure to improve their sustainability performance. Various approaches have been taken to assessing performance, and since sustainability, however defined, is a holistic quality with many different aspects, much attention has been paid to the composition of suitable *sets* of indicators or metrics (Pinter *et al.,* 2005; Bell and Morse, 2008).
Many companies now produce an annual "Sustainability Report", and the Dow Jones Sustainability Index (DJSI) has been developed to monitor how companies treat economic, social and environmental issues with regard to mitigating risk and exploiting opportunity (Searcy, 2009). The set of criteria (indicators) in the DJSI are designed to assess Corporate Sustainability, "a business approach that creates long-term shareholder value by embracing opportunities and managing risks deriving from economic,

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environmental and social developments”. This is not quite the same understanding of sustainability as that of the Brundtland Report, illustrating the importance of being clear about the working definition of sustainability used in making any assessment. Dyllick and Hockerts (2002) pointed out that many companies have adopted eco-efficiency as a guiding principle, thereby neglecting impacts on human and social affairs. Any assessment based on a restricted understanding of sustainability is bound to result in only a partial assessment of sustainability.

The Global Reporting Initiative (GRI, 2002) has developed a framework to facilitate the reporting of sustainability performance in a consistent and comprehensive way, to give such reports a similar credibility to the financial reports that have long been standard practice in the world of audited accounts. The GRI guidelines include a set of indicators having broad coverage, which demonstrate *performance* against *goals* for the organisation. The indicators are generic in nature, and for an assessment that is more focused either on business sector related concerns or local conditions, the GRI is developing respectively Sector-specific Supplements and National Annexes. An example of sector-specific sustainability metrics is the set developed by The Institution of Chemical Engineers (2002). These are consistent with the GRI approach and are intended for use by chemical manufacturing industry.

Whilst these generic methods are helpful, indicators which are not designed for any specific business or operation need interpretation and adaptation before use, and these are not well-defined processes. The resulting set of indicators may not be comprehensive in coverage of all relevant issues, or may not relate to an acceptable definition of sustainability, or may be inadequate in some other way.

2. The Process Analysis Method (Chee Tahir and Darton, 2006)

Step I: Overview of the production operation

A thorough review of the operation identifies the major processes, together with the associated process inputs and outputs, and stakeholder concerns.

Step II: Definition of Sustainability, and derivation of business perspectives

A definition of the term *sustainable development* is selected, to provide criteria or perspectives for assessing performance. Many definitions are available, but we have used that of Brundtland (1987) which is "*development, which meets the needs of the present without compromising the ability of the future generations to meet their own needs*". Though a widely accepted and carefully crafted definition, it suffers from the well-known disadvantage that it is rather too general for detailed application. Therefore we formulated some *business perspectives* which provide the link between the priorities arising from the definition, and the business processes. These are *Resource efficiency*, and *Fairness in benefit*, described further below.

Step III: System Boundary

The system boundary is determined by its spatial and temporal scales. The spatial scale is the physical size of the system. The temporal scale is the period over which the impacts of the operations are considered, which must be sufficiently large to cover inter-generational effects. The system boundary must be selected to include all the necessary features of the operation, but not drawn so widely that extraneous activities are included which could confuse subsequent analysis.

Step IV: Sustainability Framework

Within the sustainability framework we analyse the operation in a particular way, leading to selection of the indicator set, and appropriate metrics.

1. Sustainability domains and capital stores of value

We identify the sustainability domains to be environmental, economic and social, using the approach of the "triple bottom line" introduced by Elkington (1998). Each of these domains contains a store of value, termed *capital*. The operation can interact with each store of value in a variety of ways, and the stores of value experience change which may be positive, negative or neutral. This judgement is made with reference to the business perspectives formulated previously in Step II, where (i) *Resource efficiency* measures how effectively the capital is used or created (change can occur in both the amount of capital, and its quality); and (ii) *Fairness in benefit* means both (a) how fairly the benefit of using the capital is distributed, and (b) how fairly disbenefits are distributed. The first perspective incorporates the judgement that enhancing the quality and preserving or increasing the extent of the stores of value (capital) is beneficial for sustainable development. Enhancing and preserving the capital for example, will mean that more is available for future generations to enjoy (inter-generational equity). The second perspective incorporates a second judgement, which is that sustainable development is advanced by a fairer distribution of benefits which in turn promotes wider economic and social development. "Fairness" also applies to the distribution of undesirable outcomes or disbenefits such as pollution or reduction in biodiversity.

We consider the stores of value in this analysis to be (1) natural capital, (2) financial capital, (3) human and social capital. This type of thinking about capital is similar to that used by the World Bank (2005) in its approach to sustainable development.

The natural capital is the store of value contained in the natural world including natural resources, the diversity of ecosystems, the aesthetic value of natural landscapes, and so on. Financial capital is defined as cash and tangible and intangible assets that could be realised for cash. Human capital is the intrinsic value of people (knowledge and skills, resourcefulness, imagination, creativity, physical strength etc). Social capital is the extra value that people acquire through being part of a group with attributes such as organisational efficiency and altruistic behaviour. For simplicity we take human and social capital as one combined store of value - the value residing in human beings, individually and collectively.

2. Internal Impact Generators

The activities that have an impact on the stores of value are termed *Internal Impact Generators (IIG)*. These relate to activities within control of the business - hence "internal". The impacts are experienced by the owners or guardians of the capital.

3. External Impact Receivers

The owners or guardians of the capital impacted by the internal impact generators, are termed *External Impact Receivers (EIR)*. The EIR will be stakeholders, by definition.

4. Issues

Impacts of the IIG are characterised in terms of *issues* - stakeholder concerns about a particular impact. It is essential that the issues, which will be described by the indicators, do cover the extent and nature of the impact of the IIG. Identifying the set of issues is crucial in the analysis, since it leads directly to the indicator set.

5. Indicators
Indicators are used to describe the issues. Help with identifying possible indicators can be obtained from various published lists (Azapagic, 2004). The link between "issue" and "indicator" should be as simple and direct as possible.
6. Metrics
The metrics quantify the impact caused by the internal impact generators. They should be backed by scientific or other quantifiable data, and must be relevant and specific to the defined purposes. Schwarz *et al.* (2002) have noted that it will often be useful if the metrics are comprehensible to both technical and non-technical audiences, and point out the desirability of cheapness and ease of data-collection.
Step V: Verification and Modification
To ensure that the indicators and metrics are applicable to the production operation it is necessary to verify and revise the indicators and metrics through fieldwork reviews and consultation with experts and stakeholders. Finally a refined set of indicators and metrics is obtained that is both necessary and sufficient to monitor the sustainability performance of the operation.

3. Discussion

The Process Analysis Method was developed to provide a formalistic and thus transparent approach to generating a set of sustainability indicators. A first case study to check its value was carried out on an agricultural production process, the growing of oil palm in matured estates to supply palm fruit feedstock for edible oil production, and potentially for biofuel. Fieldwork with stakeholders was undertaken to clarify the analysis and the issues. This study is being reported elsewhere, but Table 1 shows the Internal Impact Generators identified for this case study. The IIG for any production operation will be similar, but not necessarily identical. For each IIG we followed the Framework analysis described in Step IV above. So for example, within the *Social domain* and for the IIG *Management of Social Capital*, the issue *Job prospects for local communities* was one of those identified: the indicator chosen was *Job creation* and the metric *Number of positions filled by locals*. The whole set of 22 IIG resulted in 72 metrics specific to the oil palm case. As shown in Table 1, most of the IIG are management activities or policies, and this will normally be the case.
Thus the Process Analysis Method has the advantage of a common approach, leading to comparability of results, but with data relevant to the specific operation. If analyses can be made for similar businesses, this will facilitate benchmarking.
By appropriate selection of the system boundary, we can focus on the sustainability performance of a particular part of a business, such as the production operation of our oil palm case study, a supply chain, a manufacturing or agricultural unit, or a product life cycle. Nevertheless, one must be cautious when determining the system boundary as it is well-known that inappropriate setting of the system boundary, which also controls the span of information and data gathering, can result in a misleading conclusion (GRI, 2005). A similar difficulty arises in Life-cycle Analysis. To avoid this outcome requires transparency and objectivity in the selection of the system boundary.
A limitation of the method is that sustainability problems or issues that arise indirectly from the activities of the business through the action of an External Impact Generator

may be left out. For example, government policy on the distribution of taxation receipts may have a significant effect on the way society experiences the benefits or disbenefits of the business operation. The extent to which our analysis should, or can, include such indirect effects is a complex question requiring further study. Partly this is a question of being clear about the definition of the system boundary, but it will sometimes be difficult to determine the precise reach of operations that are within the control of the business, but are affected by decisions or actions outside that control.

We have deduced the business perspectives by focussing on the priorities implicit in the selected definition of sustainability (ie Brundtland) and screening activities and policies to identify the characteristics of those activities that affect the stores of value.

Table 1 Internal Impact Generators derived for the oil palm production case study

Environmental domain	Economic domain	Social domain
Material management Energy management Land management Water management Biodiversity management Waste management Environmental product management Transport management Management of supplier and Contractor environmental practices	Economic product management Management of waste with economic worth Economic material management Economic human resource management Economic utility and service management Economic distribution to capital providers Economic distribution to suppliers and contractors Economic distribution to employees Economic distribution to government agencies Economic distribution to local communities	Management of human capital Management of social capital Social product management

We would expect these characteristics - what we term the business perspectives - to be fundamental elements underpinning the Corporate Social Responsibility (CSR) policy of the business. The need for a company's CSR policy to specify the values that will be used to guide the sustainability assessment of business operations has been emphasised by Labuschagne *et al.* (2005) and others. The method can be used with definitions other than that of Brundtland, but we could then expect that the business perspectives might change.

The output of the method is a list of metrics, which, depending on the business, may be rather long and not convenient for making simple comparisons. Two methods of proceeding are then possible: (a) to select a small number of key metrics from the long list, and use these as representative of the whole picture; (b) to combine metrics to form a composite metric using weighting factors, perhaps assigned with stakeholder involvement. Composite metrics can be very powerful, but they can also hide the detail of the analysis, which might be important, so they have to be used with care.

4. Conclusions

The Process Analysis Method interprets and applies the fundamental concept of Sustainable Development to the practical problem of assessing the sustainability of a production operation. Further, each metric can be traced back through the analysis to a particular operational process, which is especially helpful in guiding remedial action to improve performance.

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References

Azapagic, A., 2004, Developing a Framework for Sustainable Development Indicators for the Mining and Minerals industry, Journal of Cleaner Production 12, 639-662.

Bell, S. and Morse S., 2008, Sustainability Indicators: Measuring the Immeasurable?, Earthscan, London.

Brundtland, G. (ed)., 1987, Our Common Future: The World Commission on Environment and Development. Oxford University Press, Oxford.

Chee Tahir, A., and Darton, R.C., 2006, Using Indicator Sets to Monitor the Performance of a Sustainable Business, Proceedings of 11th Asian Pacific Confederation of Chemical Engineers Congress, The Institution of Engineers Malaysia, Kuala Lumpur.

Dyllick, T. and Hockerts, K., 2002, Beyond the Business Case – For Corporate Sustainability, Business Strategy and the Environment 11, 130-141.

Elkington, J., 1998, Cannibals with Forks: The triple bottom line of 21st century business. New Society Publishers Stony Creek, CT, USA.

Global Reporting Initiative (GRI), 2002, Sustainability Reporting Guidelines, Global Reporting Initiative, Amsterdam, Netherland.

Global Reporting Initiative (GRI), 2005, Boundary Protocol, Global Reporting Initiative, Amsterdam, Netherland.

Institution of Chemical Engineers, 2002, The sustainability Metrics: Sustainable Development Progress Metrics Recommended for Use in the Process Industries. Institution of Chemical Engineers, Rugby, England.

Labuschagne C., Brent A.C. and van Erck R.P.G., 2005, Assessing the sustainability performance of industries, Journal of Cleaner Production 13(4), 373-385.

Pinter, L., Hardi, P. and Bartelmus, P., 2005, Sustainable Development Indicators: Proposals for a way forward; UNDSD report. IISD, Winnipeg, Manitoba, Canada.

Schwarz, J., Beloff, B., and Beaver, E., 2002, Use Sustainability Metrics to Guide Decision-Making, Chemical Engineering Progress 1st July, 58-63.

Searcy, C., 2009, The role of Sustainable Development Indicators in Corporate Decision-making. IISD, Winnipeg, Manitoba, Canada.

World Bank, 2005, Focus on Sustainability 2004, Chapter 4, Our Commitment to Sustainable Development. World Bank, Washington, USA.