Universidade do Minho
Escola de Engenharia

David Rodríguez Lago

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Dissertação de Mestrado
Ciclo de Estudos Integrados Conducentes ao
Grau de Mestre em Engenharia e Gestão Industrial

Trabalho efetuado sob a orientação do
Professor Doutor Sílvio do Carmo Silva

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DECLARAÇÃO

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É AUTORIZADA A REPRODUÇÃO INTEGRAL DESTA DISSERTAÇÃO APENAS PARA EFEITOS DE INVESTIGAÇÃO, MEDIANTE DECLARAÇÃO ESCRITA DO INTERESSADO, QUE A TAL SE COMPROMETE.

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Assinatura:

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Abstract

Sustainability is an imperative of present and future production activity. Sustainability is concerned with the environment protection, safety and welfare of present and future generations. Business success, both in manufacturing and services, must be measured against results contributing to sustainability. This means that business practices must be based on strategies that assertively address not only economic issues but also social and environmental ones, the three dimensions being referred as the triple-bottom-line approach (TBL). A company must therefore strive to measure and evaluate its sustainability stand and the effects of strategies on sustainability evolution on the TBL dimensions. In the literature there are a lot of studies, guidelines and recommendations on sustainability of companies and production and sustainability reporting, but apparently there is a serious difficulty in measuring the sustainability stand and evolution of companies and production dependent on strategies, and therefore difficulty to manage production activity towards sustainability. This dissertation gives an overview of the available literature on sustainability of companies, focusing on indicators of sustainability on the TBL dimensions and on composite indicators of these dimensions, with an emphasis on production sustainability. Finally an attempt to create an index to evaluate sustainability of a company is made. This index is based on the Analytical Hierarchy Process (AHP). An example of application of this index for sustainability evaluation of a company on the TBL dimensions is presented.

Keywords

Sustainability frameworks, sustainability indicators, sustainability measurement, AHP

Resumo

As atividades industriais devem reger-se por normas e estratégias de sustentabilidade socioeconómica e ambiental. Esta preocupa-se com a proteção ambiental, segurança e bem-estar das gerações presentes e futuras. O sucesso de uma organização, na produção de bens e de serviços, deve ser avaliado à luz da sua contribuição para as três dimensões de sustentabilidade, i.e., económica, social e ambiental, referidas como o "Tripple Bottom Line" (TBL). Para tal uma organização deve implementar estratégias de sustentabilidade e ser capaz de medir e avaliar esta e a sua evolução com base indicadores relevantes. Na literatura existem muitos estudos, recomendações e orientações referentes a sustentabilidade organizacional, mas existe uma grande dificuldade em medir a sustentabilidade das empresas e da produção. Consequentemente, as estratégias para a sustentabilidade empresarial e produtiva são difíceis de definir e estabelecer. Esta dissertação apresenta uma visão geral da literatura em relação à sustentabilidade empresarial, com focagem na produção e nos indicadores de sustentabilidade associados ao TBL. Como forma de facilitar a medição sustentabilidade empresarial e produtiva desenvolve-se neste trabalho um índice flexível de medição de sustentabilidade baseado na técnica Analytical Hierarchy Process (AHP). Um exemplo de aplicação deste índice na avaliação da sustentabilidade de uma organização é também apresentado.

Palavras chave

Abordagens à sustentabilidade, Indicadores de sustentabilidade, medição de sustentabilidade, AHP

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Glossary of terms

- **Recycling:** is defined as a resource recovery method involving the collection and treatment of waste products for use as raw material in the manufacture of the same or a similar product.
- **Triple Bottom Line:** The TBL is an accounting framework that incorporates three dimensions of performance: social, environmental and financial.
- **Environmental accounting** is designed to bring environmental costs to the attention of the corporate stakeholders who may be able and motivated to identify ways of reducing or avoiding those costs while at the same time improving environmental quality and profitability of the organization.
- **Eco-efficiency:** is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity. It is based on the concept of ''doing more with less'' representing the ratio between economy and environment, with the environment in the denominator.
- **Social responsibility**: refers to safe, respectful, liberal, equitable and equal human development, contributing to humanity and the environment.
- **Eco-design:** a product development process that takes into account the complete life cycle of a product and considers environmental aspects at all stages of a process, striving for products, which make the lowest possible environmental impact throughout the product's life cycle.
- **Life cycle:** addresses all stages and the life time of products, their environmental impacts as well as services, manufacturing processes, and decision-making.
- **Life cycle assessment (LCA):** is the method/process for evaluating the effects that a product has on the environment over the entire period of its life, thereby increasing resource-use efficiency and decreasing liabilities.
- **Waste minimization:** is defined as measures or techniques that reduce the amount of wastes generated during industrial production processes.
- **Supply chain management:** is defined as a process of planning, implementing, and controlling the operations of the supply chain with the purpose of satisfying consumer requirements.
- **Environmental Management Strategy (EMS):** is a set of management tools and principles designed to guide the allocation of resources, assignment of responsibilities and ongoing evaluation of practices, procedures and processes, and environmental concerns that industries, companies, or government agencies need to integrate into their daily business or management practices.
- **ISO 14000 series**: is a family of environmental management standards developed by the International Organization for Standardisation (ISO). The ISO 14000 standards are designed to provide an internationally recognized framework for environmental management, measurement, evaluation and auditing.

- **Sustainable production**: is creating goods by using processes and systems that are non-polluting, that conserve energy and natural resources in economically viable, safe and healthy ways for employees, communities, and consumers and which are socially and creatively rewarding for all stakeholders for the short- and long-term future.
- **Sustainable development:** development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development emphasizes the evolution of human society from the responsible economic point of view, in accordance with environmental and natural processes.

1. Introduction

1.1. Scope and objectives of the work

Sustainability is about building a society in which a proper balance between economic, social and ecological or environmental dimensions, i.e. the Triple Bottom Line (TBL) need to be achieved (Gunasekaran and Spalanzani, 2011).

Sustainability has become an important issue in all spheres of life. Companies have been under increasing pressure to seriously think about their sustainable business practices, both in manufacturing and services. The pressure for promoting sustainable business practices is both external (government regulations, profit and non-profit organizations) and internal (strategic objectives, top management vision, employee safety and well-being, cost savings, productivity and quality) (Gunasekaran and Spalanzani, 2011). Today is just as important to get a good profit as to be eco-efficient and to be careful with environment and the society. A good company is also a company which cares about its employees and cares about its impact on the society. Sustainability is a reality whose results support companies' competitiveness. Sustainability and Corporate Social Responsibility (CSR) are important issues and must be equated in managing a company and setting company strategies for success.

Production sustainability is nowadays a requirement for the success of companies and a contribution for preserving earth resources for future generations, improving the quality of life and meet stakeholders' expectations. Moreover it is a requirement for sustainable competition of companies.

It is not easy to transform a company into a sustainable company. There are some issues and questions that are difficult to answer:

- How can a company become a sustainable company?
- How can sustainability be measured?
- How and which sustainability metrics and targets can be used and set?
- How does sustainability evolve over time?

A company is, therefore, confronted with the difficulty of measuring and evaluating its sustainability stand and evolution to assess the strategies set for improving production sustainability.

Strategies to overcome the difficulties and solve the problems raised must be aligned with different dimensions of sustainability. One possible view of such dimensions is the triple bottom line which identifies the environmental, economic, and social dimensions. Other views can be considered.

The problem of defining and setting suitable sustainability targets needs to take into account the dimensional framework of metrics which is adopted.

Finding a model to measure sustainability is a difficult problem to solve if sustainability within and across companies and through time need to be compared.

In the literature there is a lot of information about sustainability, but there are still quite a few issues and difficulties needing attention. Some of these have to do with measuring and evaluating company and or production sustainability in relevant dimensions as an instrument for better decision making and accomplishment of corporate social responsibility.

This master project is focused on the difficulties and problems above raised and directed towards a contribution to overcome and solve them. One planned contribution is an attempt to develop a procedure for measuring and evaluating sustainability of production. However its main contribution is the result of a literature review which 1) study and analyse frameworks and models for measuring sustainability, 2) identify and study sustainable performance indicators that are or may be used for measuring, in general, sustainable development and, in particular, the sustainability of production. The study is extended to 3) models that are used for evaluating the sustainability performance behaviour of companies and production. This evaluation is required to assess the sustainability stand of companies and also the effect of strategies designed for increasing sustainability. It can be done exploring different perspectives, among them , evaluating sustainability over time and in comparison to targets.

1.2. Structure of the dissertation

After this introduction, the 2nd chapter gives an overall view of concepts of sustainability and raises the problematic of sustainability and of related issues relevant to manufacturing companies.

Chapter 3 focusses on indicators of sustainability ranging from environmental to social and economic indicators. In this chapter we define what key performance indicators (KPIs) are, their features and some related issues. We also will talk about some lists examples of sustainable indicators that companies are using today. The same chapter also looks inside the frameworks to measure, evaluate and report sustainability based on sustainable indicators.

Chapter 4 speaks about indices or composite indicators, that provide a method for integrated sustainability assessment. These indicators integrate economic indicators, social indicators, and environment indicators, and blends of them in composite indicators. These, together with other indicators can help companies in decision-making relative to sustainable development or sustainable production.

Chapter 5 attempts to give a critical overview about frameworks and methods described in chapters 3 and 4. The same chapter tries to develop an approach to evaluate sustainability of a company. It finishes with an example analysis of the sustainability of the Grupo Bimbo in a period of three years.

Chapter 6 presents the conclusions and future work related to this dissertation.

2. Sustainable production – fundamental concepts and definitions

2.1. Definitions of sustainable production

Sustainable production is part of the broader concept of sustainable development that emerged in the early 1980s in response to increased awareness raising and concern about the environmental and social impact of economic growth and expansion of the global economy.

According to a UN document (web site [1]) sustainable development is the development which satisfies the needs of the present without compromising the ability of future generations to meet their own needs.

At the 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, sustainable production was introduced and adopted as one of the guiding principles for business and governments in transitioning towards and achieving sustainable development.

As sustainability is becoming an expected business practice by companies, large and small, sustainable manufacturing or production is being defined, developed and implemented by manufacturing companies and their networks of suppliers and customers. Some definitions are summarized in Table 1:

Table 1 .Different definitions of sustainable manufacturing (Leahu-Aluas, 2010)

Reference	definition
Department Of Commerce USA	Sustainable manufacturing is the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound (Leahu-Aluas, 2010)
Lowell Center for sustainable production	Sustainable manufacturing is the creation of goods and services using processes and systems that are: • Non-polluting • Conserving of energy and natural resources • Economically viable • Safe and healthful for workers, communities, and consumers • Socially and creatively rewarding for all working people.
Institute For Manufacturing, University of Cambridge	Sustainable manufacturing is the developing technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste.
Sustainable Manufacturing Consulting, Indianapolis	Sustainable manufacturing is a business practice of the industrial sector, which expands all the company's processes and decisions into the social and natural environments it operates in and affects, with the explicit objective of reducing or eliminating any negative impact, while pursuing the desired level of technological and economic performance.

Sustainable manufacturing involves making more efficient use of natural resources and energy, besides reducing emissions of greenhouse gases and other environmental consequences. The goal is to serve basic needs for goods and services, at the same time improving the quality of life and guaranteeing for the future generations sufficient resources.

Development of a sustainable manufacturing system adds more parameters to be handled simultaneously. This is a problem if the decision-makers need to handle a multitude of different parameters that are not incorporated into the analysis of one single simulation (Mason and Hill, 2008).

2.2. The function of the society in sustainable development.

Working for sustainable development means not only partially compensate negative externalities of the company through philanthropic projects, considering these like collateral damage effects which may be "compensate" by, for example, sponsorship of tree plantations. The company can go beyond compensation in the environmental field, because the model of sustainable development must also respect the balance between economic and social dimensions and between it and the protection of the environment (Alfaya and Blasco, 2002).

2.2.1.What characterizes the "Sustainable Company"?

A sustainable company is one that obtains economic benefits designing products and services that improve quality of life for its customers, employees, suppliers, local communities and other groups involved, works for a possible future providing value for society that tries to serve. To walk in this direction, Alfaya and Blasco (2002) say that a company to be socially responsible needs a system of government suitably aligning the organization and the value chain of its products and services accordingly,

Table 2.

Table 2. The evolution from the conventional perspective of doing business to what we would call a "sustainable business"(Alfaya and Blasco, 2002).

Conventional company	socially responsible company	Sustainable company
Maximize profit for shareholders	Maximize profit for shareholders reversing a portion to the society where it operates in order to partly compensate the negative externalities that produces	Maximize profit for society where it operates creating new products and services
Enforce the rules of the game	avoid harmful effects that may have the products and services it offers on the market	takes advantage of opportunities that better quality of life offers for business
Meet demands for information	Show their social commitment	promote participation of society on the company to jointly seek solutions

New responsibilities should involve new laws that must be enforced for all	We need few rules	We need few rules
Reactive position	**Proactive position**	**Leadership**

2.2.2.What is Corporate Social Responsibility?

Corporate Social Responsibility (CSR) is a management concept whereby companies integrate social and environmental concerns in their business operations and interactions with their stakeholders. CSR is generally understood as being the way through which a company achieves a balance of economic, environmental and social imperatives ("Triple-Bottom-Line-Approach"), while at the same time addressing the expectations of shareholders and stakeholders.

Thus, CSR appears as a form of voluntary commitment of the company with the internal and external environments to achieve sustainable development and agreement between both parts (Freeman and Hasnaoui, 2010). In brief, CSR search a relationship of the company that is responsible, transparent and based on mutual respect, with each of the stakeholders or parties involved as shown in Figure 1(Kakabadse et al. 2005).

Thus, it is necessary to analyse the different ways in which CSR is developed, which can split the company's CSR as follows (Davies 2003, Kotler and Lee 2005):

- CSR Internal: it refers to responsible behaviour in the internal context of the company and affects two key elements: the governability of the organization, it means the significant improvement of their systems of government, and labour relations in the company.
- CSR external: it refers to responsible behaviour in the iteration of the company with their external stakeholders regarding sustainable economic growth, fight against corruption, protection and conservation of the environment and search for greater social equality.

As shown in the CSR wheel of a company, Figure 1 there are 8 stakeholders groups, and in each group there are some indicators, that totally account 56, Table 3

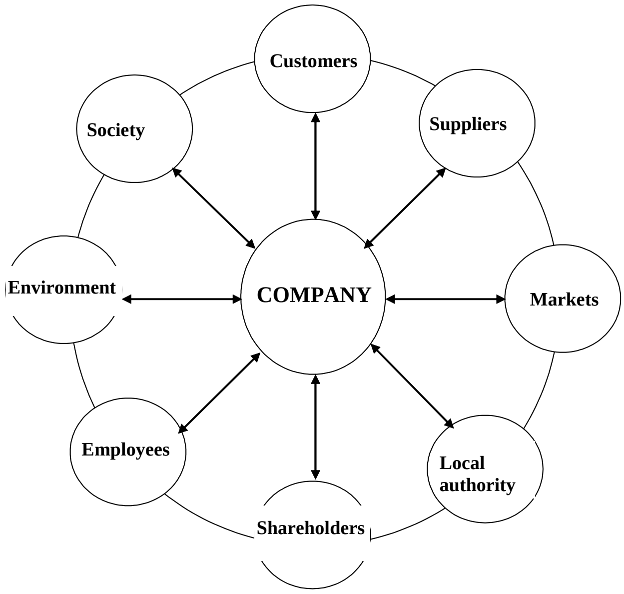

Figure 1. The CSR wheel of a company (adapted from Kakabadse et al. 2005).

Table 3. Indicators for 8 stakeholders groups. Vilanova and Dinarès (2009)

stakeholder	Indicator	impact on the company
employeers	economic value generated	
	salary of the employees	
	labor conditions on the workplace	
	evaluation of the results	
	work absenteeism	
	profile of the group of workers	
	training of the staff	
	rotation of staff	
	conciliation of the work life, personal,and family	
	human rights	
	equally oportunity programs	
	waste produced	
	independent external environmental verification	
	Recycling	
	workplace accidents and diseases	
	Formal representation of workers in management	
	syndicate or collective representation	
	health and safety policy at work	
	harassment and abuse	

Supplier	conditions and average payment time	
	training of the staff	
	human rights	
	good practices with local suppliers	
	selection, evaluation, and association with suppliers	
customers	customer satisfaction	
	human rights	
	product liability	
	retention and customer loyalty	
	product claims	
	impact social marketing	
	environmental management system	
	customers privacity	
	communicative product liability	
	selection, evaluation, and association with suppliers	
local authority	economic value generated	
	investments and services that provide a social benefit	
	relations with political authorities and lobby	
	government subsidies	
Society	human rights	
	economic value generated	
	relationship with the community	
	awards and distinctions for responsible acting	
	investments and services that provide a social benefit	
Market	communicative product liability	
shareholders	economic value generated	
	customers privacity	
	communicative product liability	
	selection, evaluation, and association with suppliers	
environment	Energy and water consumption	
	environmental conditions in the workplace	
	independent external environmental verification	
	Recycling	
	environment management system	
	gas emissions	
	effluent emissions	
	Biodiversity	

If a company wants to apply the CSR, it must analyse first which of these key CSR issues have greater impact, second, those which manages currently and, finally, where would advance the future.

2.3. Life cycle assessment concepts and methodology

Sustainable manufacturing must be eco-efficient. One method used for evaluating this is Life Cycle Assessment (LCA). Life cycle assessment was developed as an analytical tool to help assess the environmental impacts from products or services. For a product to perform its function it must be developed, manufactured, distributed to its users and maintained during use (Hauschild et al., 2005). In order to get an impression of the total environmental impacts caused by the product, the analysis must focus on the product system or the life cycle of the product which is shown, in a general form,as shown in Figure 2.

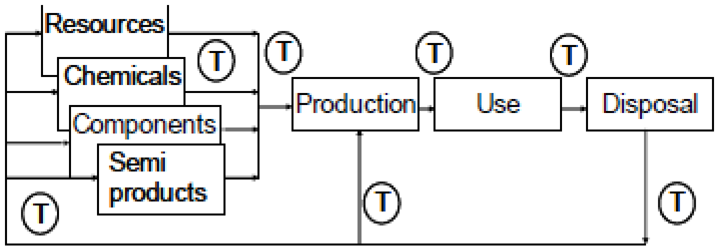

Figure 2.The product system or life cycle of a product (Hauschild et al, 2005).

In an attempt to support a global dissemination of the interest in environmental performance of products, the United Nations Environment Program in 2002, in collaboration with The Society of Environmental Toxicology and Chemistry (SETAC), launched the Life Cycle Initiative under the United Nations Environment Program (UNEP) Program for Sustainable Consumption. The initiative has the mission: 'To develop and disseminate practical tools for evaluating the opportunities, risks, and trade-offs associated with products and services over their whole life cycle' (Hauschild et al. 2005). A global user survey performed for guiding the definition of the Life Cycle Initiative revealed that for the impact assessment phase of Life Cycle Assessment (LCA), the highest priorities of users are(Stewart and Jolliet, 2004):

- Transparency in the methodology.
- Scientific confidence and co-operation.
- Development of recommended factors and methodologies with uncertainty described.
- Development of methodology for impact categories with specific relevance for developing countries (salinization, erosion, soil depletion).

The Life Cycle initiative was organised in three pillars addressing respectively life cycle inventory analysis, life cycle impact assessment, and life cycle management (the use of life cycle assessment information in management decisions), Figure 3. The tasks addressed by each one are:

- **Life Cycle Inventory (LCI):** Agreement on data quality characterisation and data reporting formats facilitation of access to existing LCI databases and to LCA studies which have been published in some form.
- **Life Cycle Impact Assessment (LCIA)**: Facilitation of access to existing LCIA methods in the short term and development of recommendable practice for the different impact categories and for assessment of resource consumption in the medium and long term (2-5 years).
- **Life Cycle Management (LCM):** Integration of existing tools and concepts for decision making on more sustainable products and services in a life cycle management

framework, communication of life cycle information to relevant stakeholders, training modules for SMEs and developing countries.

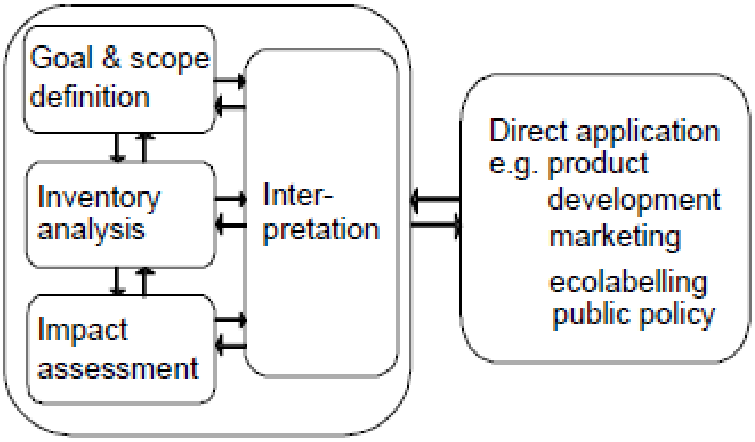

Figure 3.The framework of life cycle assessment according to the ISO 14040 standard (Hauschild et al, 2005).

LCA methodology

The LCA methodology in important to evaluate the environmental performance of products, services and processes and it is considered a powerful tool for decision makers. Waste treatment options are frequently evaluated using LCA methodologies in order to determine the option with the lowest environmental impact. Typically, industrial modelling with LCA describes static models compared to discrete event simulation (DES) (Mason and Hill, 2008). A product should be examined from the initial extraction and processing of raw materials through manufacturing, distribution and use to final disposal, including the transport involved, i.e. its whole life cycle (Figure 4).

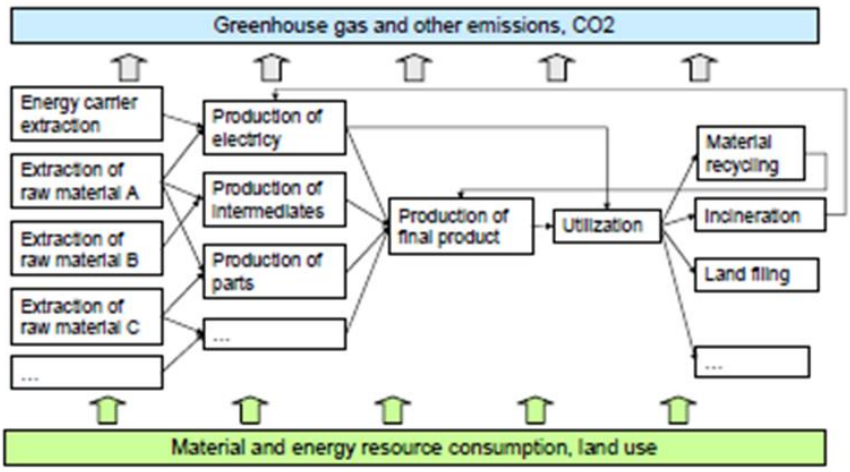

Figure 4. Product life cycle, based on EU LCA platform. (Mason, 2008).

Persson and Karlsson (2007), Alvemark and Persson (2007), and Ingvarsson and Johansson (2006) used DES as a tool for environmental measurements in food production. A combination of LCA and DES was employed.

There are five LCA metrics that were incorporated in the DES models:

1- Carbon Emissions, tons CO2 Equivalent

2- Air Pollutant Emissions, tons or kg

3- Liquid Waste Generate, tons or kg

4- Solid Waste Generate, tons or kg

5- % Recycled Waste, percent

These metrics can be applied in the fabrication phase, at the factory level or even in a single manufacturing phase.

The life cycle impact assessment proceeds through four steps (Hauschild et al, 2005):

- First step is *Selection of impact categories and classification*. Here, categories of environmental impacts of relevance to the study are defined. In most LCA studies, existing impact categories can just be adopted. Next, the substance emissions from the inventory are assigned to the impact categories according to their ability to contribute to different environmental problems. Figure 5 illustrates environmental impact categories which are often modelled in LCIA

- Second step is *Characterisation* where the impact from each emission is modelled according to the environmental mechanism (Figure 5) and expressed as an impact score in a unit common to all contributions within the impact category (e.g. kg CO2-equivalents for all greenhouse gases).

- Third step is Normalisation. Normalisation expresses the magnitude of the impact scores on a scale, which is common to all the categories of impact (typically the background impact from society's total activities). In the example of

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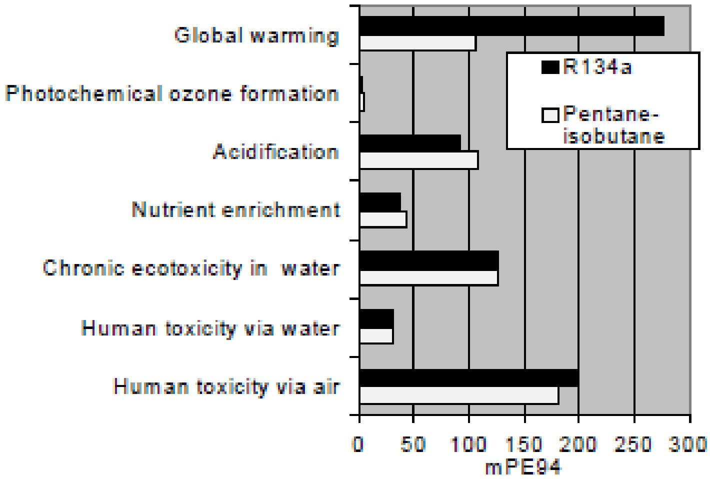
- Table 4 the impact scores are expressed in *person equivalents, PE*. The unit PE represents the annual impact from an average person and is useful for bringing the rather diverse environmental impacts on a common scale.

Table 4. Impact profiles for two refrigerator designs. All impacts are normalised and expressed in a common unit– the person equivalent, PE (or rather milli PE).



- Fourth and final step of the impact assessment is *Valuation* where a ranking or weighting is performed of the different environmental impact categories and resource consumptions reflecting the relative importance they are assigned in the study. The valuation is needed when trade-off situations occur as described under normalisation. Where normalisation expresses the relative magnitudes of the impact scores and resource consumptions, valuation expresses their relative significance considering the goal of the study.

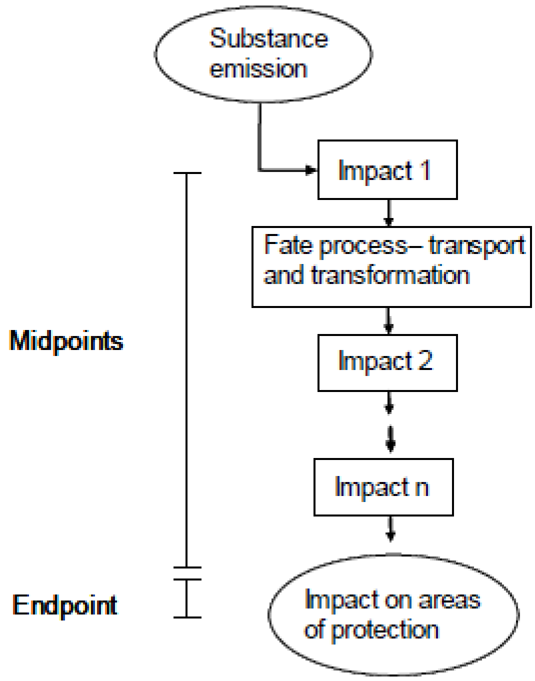


Figure 5. Modelling of the impacts, which emissions cause on areas of protection (Hauschild et al, 2005).

2.4. Ecological footprint

As Wackernagel and Rees (1996) point out:

- Human demand on ecosystem services continues to increase, and there are indications that its demand is outpacing the regenerative and absorptive capacity of the biosphere. For this reason the productivity of natural capital may increasingly become a limiting factor for the human endeavour. Therefore, metrics tracking human demand on, and availability of, regenerative and waste absorptive capacity within the biosphere are needed to track minimum sustainability conditions. The ecological footprint is a measure of human demand on the Earth's ecosystems. It is a standardized measure of demand for natural capital that may be contrasted with the planet's ecological capacity to regenerate. It represents the amount of biologically productive land and sea area necessary to supply the resources a human population consumes, and to assimilate associated waste. Using this assessment, it is possible to estimate how much of the Earth (or how many planet Earths) it would take to support humanity if everybody followed a given lifestyle.
- Ecological Footprint and biocapacity calculation covers six land use types: cropland, grazing land, fishing ground, forest land, built-up land, and the uptake land to accommodate the carbon Footprint. For each land use type, the demand for ecological products and services is divided by the respective yield to arrive at the Footprint of each land use type [Ewing B. et al. 2010]. Ecological Footprint and biocapacity are scaled with yield factors and equivalence factors to convert this physical land demanded to world average biologically productive land, usually expressed in global hectares (gha). This allows for comparisons between various land use types with differing productivities.

- The National Footprint Accounts calculate the Ecological Footprint and biocapacity for more than 200 countries and the world. According to the 2010 Edition of the National Footprint Accounts, humanity demanded the resources and services of 1.51 planets in 2007; such demand has increased 2.5 times since 1961. This situation, in which total demand for ecological goods and services exceeds the available supply for a given location, is known as overshoot. On the global scale, overshoot indicates that stocks of ecological capital may be depleting and/or that waste is accumulating.

Ecological Footprint accounting is based on six fundamental assumptions (Wackernagel et al. 2002):

- The majority of the resources people consume and the wastes they generate can be quantified and tracked.
- An important subset of these resource and waste flows can be measured in terms of the biologically productive area necessary to maintain flows. Resource and waste flows that cannot be measured are excluded from the assessment, leading to a systematic underestimate of humanity's true Ecological Footprint.
- By weighting each area in proportion to its bioproductivity, different types of areas can be converted into the common unit of global hectares, hectares with world average bioproductivity.
- Because a single global hectare represents a single use, and each global hectare in any given year represents the same amount of bioproductivity, they can be added up to obtain an aggregate indicator of Ecological Footprint or biocapacity.
- Human demand, expressed as the Ecological Footprint, can be directly compared to nature's supply, biocapacity, when both are expressed in global hectares.
- Area demanded can exceed area supplied if demand on an ecosystem exceeds that ecosystems regenerative capacity.

3. Decision indicators and frameworks to measure sustainability

3.1. Introduction

Achievements are evaluated by performance or decision metrics. These can serve as basic tools to guide a company to keep or become sustainable. they may include essentially two types: indicators and indices. Indicators, indices, and parameters are frequently referred as the same. However, in general, there are many parameters, less indicators and only a few indices. A parameter is a variable carrying some useful information about the system or system operation with which it is related. We could say that it is little more than a datum useful for system understanding, characterization and performance evaluation. For example, the total number of manufacturing employees of a company and the production output are parameters. Although parameters may be useful, alone they tell very little about the system and its performance or business achievements. Indicators are metrics that relate, in a simple and linear manner, two or more parameters for providing quantitative and or qualitative information about a system operation or activity performance during a given period. For example the relation between output and the number of employees is an important indicator, i.e. productivity. Che B. Joung, et. al 2012 define an indicator as a measure or an aggregation of measures from which conclusions on a phenomenon of interest can be inferred.

Unless otherwise said or taken from context, in this dissertation, we use the term indicator to refer a decision metric, either indicator or index.

Indicators of an organisation activity or performance can be characterized by the following attributes (Che B. Joung et al., 2012):

- **Identification (ID)**: the unique alphanumeric identifier
- **Name:** the word(s) for the distinctive designation
- **Definition:** the statement expressing the essential characteristics and function.
- **Measurement type**: the type of metric: quantitative or qualitative.
- **Unit of measure:** the unit of the value measured.
- **References:** citable documents of existing metrics set(s) or specific metrics(s), based on which a metric is based.
- **Application level:** the level in a hierarchical organization that the indicator is applied.

Parameters and indicators are useful to develop indices. Real indices are variables or metrics giving a good overall and aggregated understanding or evaluation of system performance or activity. Complex models of supposed indices that do not give this understanding are of little use.

Indices relate parameters and or indicators through mathematical models of several degrees of complexity. Examples of indices are, Overall Equipment efficiency (OEE) (Puvanasvaran et al., 2013),the Ecological Footprint (EF) (Wackernagel and Rees, 1997) Environmental

Sustainability Index (ESI) (Esty et al. ,2005), composite sustainable development index (Damjan Krajnc, Peter Glavic,2003).

Sustainability indicators are indicators that measure sustainability. While the number of sustainability indicators in the literature is growing, none of them advances our understanding of corporate sustainability. It is not possible to have a set of sustainability indicators, applicable to all organizations because organizations vary enormously in their business activities and objectives. Therefore, frameworks for measuring sustainability performance are necessary to help a company to achieve sustainability. Frameworks give guidelines and support for companies that help them to define targets and to evaluate and achieve sustainability.

Some of the best-known indicator frameworks are the International Organization for Standardization ISO 14031, Global Reporting Initiative (GRI), Lowell Center for Sustainability Production (LCSP) indicator framework, Dow Jones Sustainability Indexes (DJSI), Ford Product Sustainability Index (Ford PSI), European Environmental Agency Core Set of Indicators (EEA-CSI) etc. In this dissertation we make a brief description of some, i.e. GRI, LCSP.

In the next section we define what KPIs are, and we also give examples of sustainable indicators that companies are using today.

3.2. Selecting and Defining Key Performance Indicators - KPIs

It has become popular in the last decades to refer to metrics, either indicators or indices, measuring the degree of goals or objectives' achievements, i.e. of success, of a company or production, as key performance indicators (KPI) (web site [2]). Thus, KPIs are metrics used to quantify the results of a particular action aligned to the objectives that are key or very important to a company.

Companies can design their KPIs based on the SMART criterion of Peter Drucker (Bogue, 2013):

- **Specific:** The criterion stresses the need for a specific goal rather than a more general one.
- **Measurable**: By definition a KPI should be measurable.
- **Achievable**: The objectives that we will consider when we are setting our KPIs must be credible.
- **Relevant:** Sometimes the excess of information can be a problem and we have dozens of KPIs to choose but few of this give information of interest; if it is enough four KPIs, better than six.
- **Timely**: The KPIs must conform to a reasonable timeframes. For example, if my goal is to increase sales by about 20% in the first quarter of the year, I can´t use as KPI the number of annual sales.

Indicators can measure efficiency and effectiveness. The concept of efficiency loss is usually interpreted as the "level of waste", considering that a process is said efficient when many products with few inputs are generated. Effectiveness is similar to efficiency, although it relates the amount of resources used to achieve business objectives.

To develop simple and meaningful KPIs, the seven simple steps shown in Figure 6 and below described, are recommended (web site [3]):

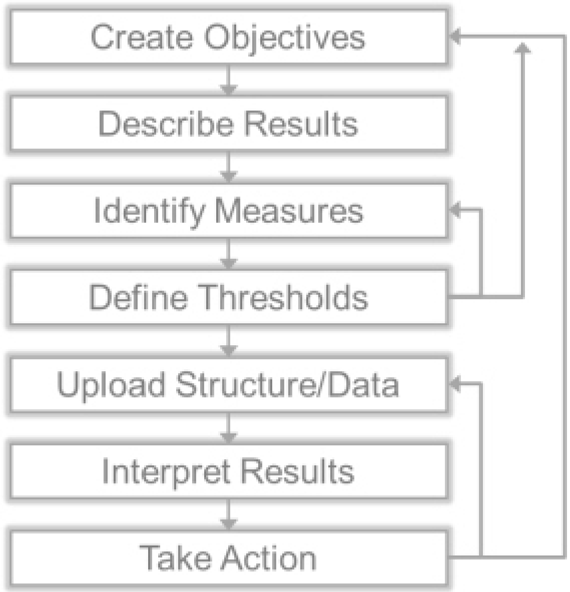


Figure 6.Seven steps to develop a KPI (web site [3]).

- Step 1 – Create Objective: An easy start, for any given area within the business, think of something that needs to be done to improve activities in that area and write it down. For example, in sales you may want to "Improve Sales Productivity".
- Step 2 – Describe Results: Often objectives are written as activities, the example above "Improve Sales Activity" is exactly this case. Worse still, objectives are often written as actions or projects, for example "Implement a Sales Plan". This may be a worthwhile activity, but it is not a measurable objective. An Objective is not an activity or a project, it is a result. Step 2 takes the Objective and refines it to use terms oriented around results and language that is specific to outputs that can be measured. For example from the aspirational objective "Improve Sales Productivity" several objectives may be derived including "Reduce the time it takes to convert a qualified lead into a sale".
- Step 3 – Identify Measures: For each objective there may be several KPIs. The selection of the KPIs must be based on things that can actually be counted or calculated. The KPIs, like the objectives need to be written clearly. For the example above "Reduce the time it takes to convert a qualified lead into a sale" there are several things that can be counted like the number of qualified leads, or the number of sales related to the leads etc.
- Step 4 – Define Thresholds: A performance measure is meaningless unless it can be compared to something. The actual value of the measure has to be compared to what would be considered good, bad or indifferent. The comparator could be a target based on previous performance or on a notional future performance. Whatever the target, it needs to be considered as reasonable and achievable. Step 4 goes through the

reasoning behind setting a target value and then on to define ‘threshold’ values. These enable the performance measure to be viewed not only as a number, currency or percentage but also visually.

- Step 5 – Upload Structure/Data: It is only at this stage that the objectives and metrics ‘structure’ should be loaded into a performance management system. Most systems will allow you to move objectives and performance measures around after they have been loaded so it is not yet necessary to have a complete view as to what the overall structure should look like. Step 5 shows how to build a scorecard structure, entering objectives and related performance measures and then arranging them for ease of access.
- Step 6 – Interpret Results: Once a set of objectives and performance measures has been entered into the system then the job of interpreting the results can be started. There are two phases to this activity, first to create a set of meaningful dashboards and reports from the data and second to interpret the results as displayed on the dashboard and in the reports when actual values have been entered. The first task, creating dashboards and reports, is not a one-off activity, it will require modification over time. The second, interpretation, is an on-going activity that occurs during the reporting cycle, usually monthly.
- Step 7 – Take Action: Any performance measure that shows (through the correct interpretation) that an objective is moving in the wrong direction may need to have an action associated with it to remedy the situation. The action may take the form of a task, project, activity, budget change or simply to remove the objective.

3.3. OEE, definition and methodology

OEE (Overall Equipment Effectiveness) is a composite indicator or index that is commonly used by leading companies. OEE aims at making a constraint or bottleneck equipment run more effectively. OEE and its individual measures and indicators, give the plant numbers to see where the equipment is losing time (Hogfeldt, 2005). Successful computation of OEE requires reliable data which reflects the real equipment utilization based on the utilization estimated, managers can identify the causes of the time losses and attempt to reduce these losses (Ki and Philip, 2001).

OEE measurement is also commonly used as a key performance indicator (KPI) in conjunction with lean manufacturing efforts to provide an indicator of success, however OEE indicator can be indirectly related with sustainability concepts and aspects, because varying variables of the OEE equation like Planned production time, or quality rate, will affect sustainability aspects like the use of raw material, or maybe social aspects like number of work hours etc. Then, it is important to include this meaningful indicator in this dissertation.

OEE is based on a number of production related variables associated with the so called six big losses. The associations are relevant to explain the components of the OEE KPI.

The variables to establish the OEE KPI are:

- Total time,
- Planned production time,
- Actual production time,
- Ideal run rate, and
- Cycle time.

Cycle time can be divided in components and interpreted in a few different ways.

A definition of each variable is:

- **Total time**: total time that the equipment is availability to work (normally 480 minutes/work shift)

- **Planned production time, Tdp**: time that the equipment could be working per shift. It will be calculated subtracting to the total time planned stopping time like equipment´s preventive maintenance, break time, underload planned stopping time… definitely all planned stopping time.

- **Actual production time, Tu**: time that the equipment has been working per shift. This is the planned production time minus those events that stopped the planned production time during an appreciable time which they were registered in the documents of the works production day (normally unplanned stopping time, breakdowns and machine adjustments).

- **Effective operating time**: This is actual operation time minus time lost due to the rejected parts during production and reworking pieces, and the losses from initial start-up to process stabilization.

- **Ideal run rate,** $\frac{T_u}{C}$ **:** this is the quantity of production during the actual production time if the equipment goes to the theoretical maximum speed available in a shift, i.e. based on the planned cycle time per unit for maximum output.

- **Current run rate, Q**: units of production of the equipment in a shift. The differences between ideal run rate and current run rate are losses in the production because micro-stopping time that are not registered in the documents of incidences and slow production velocity.

- **Current good quality rate *Qq***: units of production satisfying quality specifications (good units) of the equipment in a shift.

- **Cycle time C**: The time it takes to do one repetition of any particular task typically measured from “Start to Start”, or the starting point of one product’s processing in a specified machine or operation until the start of another similar product’s processing in the same machine or process.

  - Manual Cycle Time: The time loading, unloading, flipping/turning parts, adding components to parts while still in the same machine/process.

  - Machine Cycle Time: The processing time of the machine working on a part.

- Auto Cycle Time: the time that a machine runs un-aided (automatically) without manual intervention.
- Overall Cycle Time: The complete time it takes to produce a single unit. This term is generally used when speaking of a single machine or process.
- Total Cycle Time: This includes all machines, process, and classes of cycle time through which a product must pass to become a finished product.

Overall equipment effectiveness (OEE) is a hierarchy of metrics developed by Seiichi Nakajima in the 1960 to evaluate how effectively a manufacturing operation is utilized. OEE is a set of metrics that bring clear focus to the key success drivers for manufacturing enterprises. It is a percentage number that is usually defined by multiplying the calculated availability rate, performance rate and quality rate. These are defined as follows:

$$Availability = \frac{Actual\ Production\ Time}{Planned\ Production\ Time}$$

$$Performance = \frac{Current\ Run\ Rate}{Ideal\ Run\ Rate}$$

$$Quality = \frac{Good\ Product}{Total\ Product}$$

$$OEE = Availability \times Performance \times Quality$$

where:

- **Availability U**: is a percentage number that shows how often the machine is available where it is needed for production. It accumulates to the first two of the 6 Big Losses (Puvanasvaran et al., 2013): breakdowns and setup/adjustments which is the downtime that is measured at the equipment.

- **Performance Ip**: takes into account the unrecorded downtime which is the 3rd and 4th of the 6 Big Losses. The ideal cycle time is needed to calculate the performance efficient where it is multiplied with the total parts produced divided by the actual operating time (Mei,2013).

- **Quality Iq**: The quality rate captures the last two of the 6 Big Losses; time lost due to the rejected parts during production and reworking pieces, and the losses from initial start-up to process stabilization. This is the ratio between current production subtracting rejected parts (with or not rework) and the current production (Alagendran, 2013).

Thus OEE can be written as:

$$OEE_q = \frac{T_u}{T_{dp}} \times \frac{Q}{\frac{T_u}{C}} \times \frac{Q_q}{Q} \qquad (1)$$

From where:

$$OEE = \frac{C \times Q_q}{T_{dp}} \qquad (2)$$

Where the availability U is

$$U = \frac{T_u}{T_{dp}} \qquad (3)$$

The performance Ip is

$$Ip = \frac{Q}{\frac{T_u}{C}} \qquad (4)$$

Where:

$$Ideal\ run\ rate = \frac{T_u}{C}$$

And the quality Iq is

$$I_q = \frac{Q_q}{Q} \qquad (5)$$

The Six big loses

The six big losses and their relation to the referred variables are shown below. To be able to better determine what is contributing to the greatest loss and so what areas should be targeted to improve the performance, these categories (Availability, Performance and Quality) have been subdivided further into what is known as the 'Six Big Loses' to OEE (Figure 7).

These are categorised as follows in Table 5:

Table 5. Six big losses

Availability	Performance	Quality
Planned Downtime	Minor Stops	Production Rejects
Breakdowns	Speed Loss	Start up losses

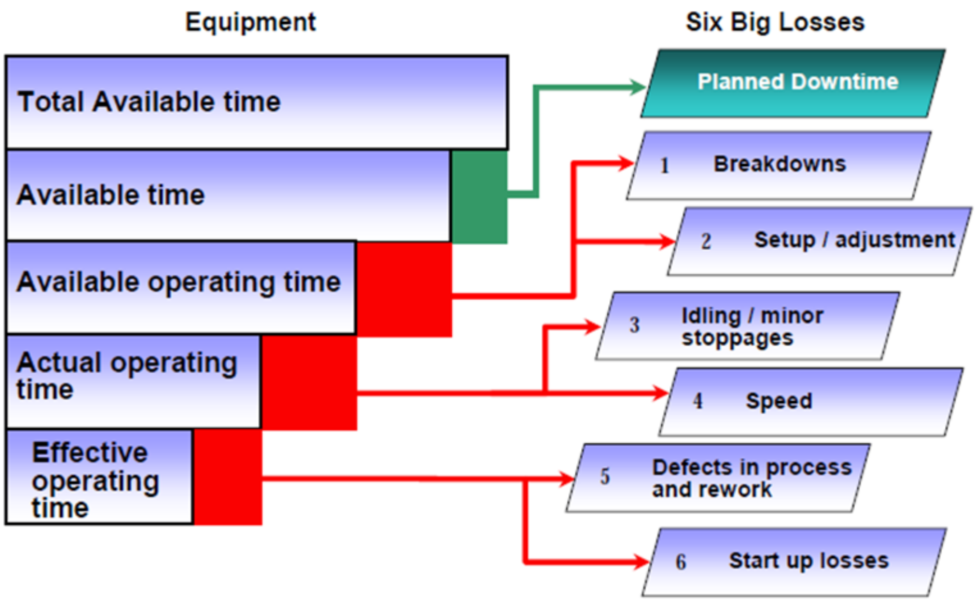


Figure 7. Avaliable operating time is the same as our TDP, and actual operating time is the same as our Tu, effective operating time is actual operating time minus time that we loss in the start up losses and reworking pieces (web site [4])

Table 6. Calculation of each big loss

Six loss category	Calculation
PDT or external unplanned event	Planned downtime / Total production time
Breakdowns (>5mins)	Major fault time / Total production time
Minor stops (<5mins)	Minor fault time / Total production time
Speed loss	((Output / actual speed) – (Output / Rated speed))/Total production time
Production rejects	Rejects in production / (actual speed X Total production time)
Star up losses	Rejects on start up / (actual speed X total production time)

Table 7. Different reasons for each big loss.

Six loss category	OEE measure	Reason for loss
1. Planned downtime	Availability	1.Changeovers 2.Planned maintenance 3.Material shortages 4.Labour shortages
2. Breakdowns	Availability	1.Equipment failure 2.Major component failure 3.Unplanned maintenance
3. Minor stops	Performance	1.Fallen products 2.Obstruction 3.Blackages 4.Misaligment
4. Speed loss	Performance	1.running lower than rating speed 2.untrained operator not able to run at nominal speed 3.Misaligment
5. Production rejects	Quality	1.Product out of specification 2.Damage product 3.Scrap
6. Start up losses	Quality	1.Product out of specification at start run 2.Scrap created before nominal running after changeover 3.Damaged product after planned maintenance activity

Companies should seek to reduce as much as possible each of the big losses if they want to increase de efficiency and obtain a good OEE indicator.

When machines are optimally tuned to accomplish the desired work, increased operating efficiency reduces energy waste.

Waste elimination is one of the most effective ways to increase efficiency and profitability of any business. Processes either add value or waste during the production of goods or services.

TPM (Total Preventative Maintenance), similarly to OEE (Overall Equipment Efficiency) methodology, identifies the losses that lower equipment efficiency, e.g. waiting, set-ups, and reduced speed [S. J. Mason, 2008]. Emphasis on equipment efficiency can lead to reduced costs, increased productivity, and fewer defects. Eradicating waste and losses in the design phases maximizes the productivity of equipment throughout its lifetime.

3.4. TEEP (Total Effective Equipment Performance)

Where OEE measures effectiveness based on scheduled hours, TEEP measures effectiveness against calendar hours, i.e.: 24 hours per day, 365 days per year. TEEP, therefore, reports the 'bottom line' utilization of assets.

A machine with high production efficiency will has a high OEE, but if we make very short use of it this will be evidenced by a low TEEP (web site [5]).

TEEP is given by

$$TEEP = Availability \times Performance \times Quality \times Utilization$$

where

$$utilization = \frac{theoretical\ maximum\ production\ at\ the\ scheduled\ time\ for\ production}{theoretical\ maximum\ output\ on\ total\ calendar\ time}$$

Possible alternative interpretations of TEEP use different "total calendar times", e.g., considering five days per week instead of seven.

The important thing is to take into account these considerations when we interpret the data and make comparisons.

3.5. Sustainable indicators – classes and dimensions

Sustainability indicators serve as basic tools to guide a company to define strategies, to establish goals and targets and, to evaluate results of its operations, to take decisions to maintain or improve its sustainability stand. Companies that need to evaluate their stand and evolution on sustainability take decisions and adopt goals and targets, based on achievements or failures of sustainability.

According to Booysen (2002) characteristics of indicators to measure sustainability are:

- Aspects of the sustainability to be measured by indicators.
- Techniques/methods/tools used for development of index like quantitative/qualitative, subjective/objective, cardinal/ordinal, unidimensional/multidimensional.
- Whether the indicator compare the sustainability measure across ‘cross-section’ or ‘time-series’), absolute or relative manner?
- Does the indicator measure sustainability in terms of input (‘means’) or output (‘ends’)?
- Clarity and simplicity in its content, purpose, method, comparative application and focus.
- Availability of data for the various indicators.
- Flexibility in the indicator for allowing change, purpose, method and comparative application.

One way to classify and analyse sustainable indicators is dividing them in three groups based on the three dimensions of the so-called triple bottom line, i.e. social, environmental and economical, Figure 8.

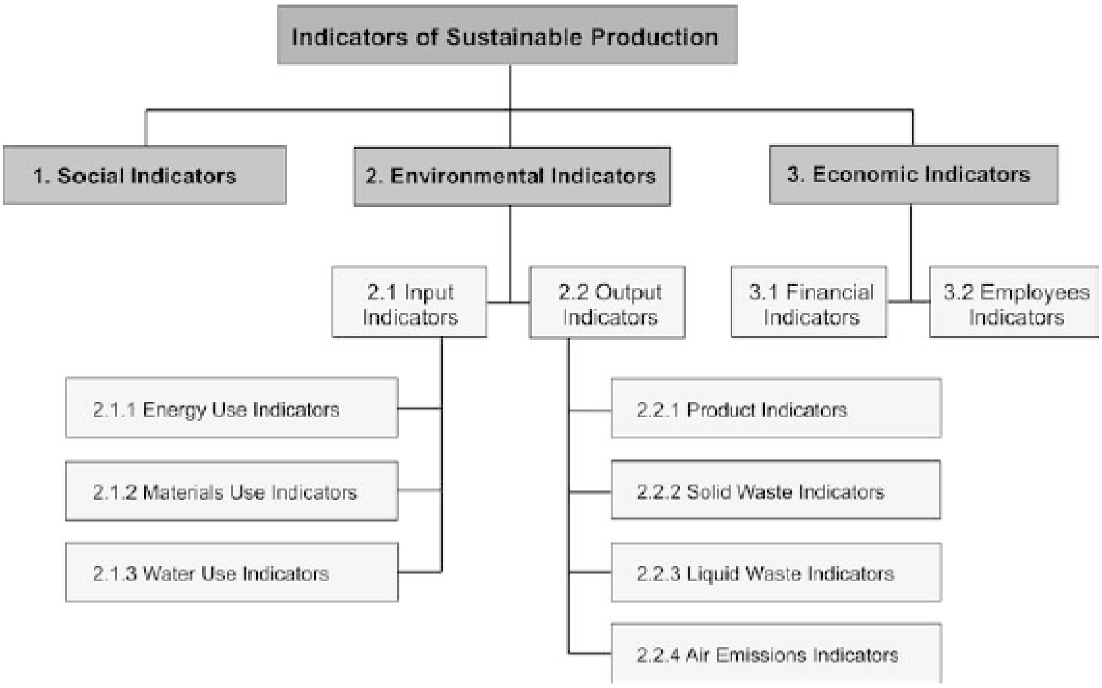


Figure 8. Division of the sustainability indicators in social, environmental and economic aspects. (Krajnc and Glavic, 2003)

Damjan Krajnc and Peter Glavic (2003) present quite many examples of indicators that could be applied for measuring sustainability in general and production sustainability in particular, as shown in Table 8. They are simple and easy to use, to measure typical aspects of production (e.g. materials use, energy use, water consumption, products, waste, air emissions, etc.). The environmental indicators are divided into input and output indicators as shown in Figure 8, dependent on input and output flows in a manufacture system as shown in Figure 9. The economic indicators are divided into financial and employees' indicators.

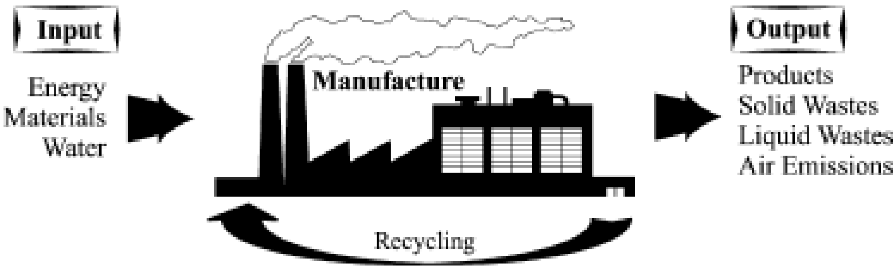


Figure 9. Flows in manufacture (Krajnc and Glavic, 2003).

Table 8. Indicators of sustainable production (Krajnc and Glavic, 2003)

Indicator		Quantity	Symbol	Unit
1. Social indicators				
1.	Specific employee number	Number of employees/unit of production	$N_{employee}$	1/UP
2.	Employee turnover[a]	Number of employees who have resigned or been made redundant/total number employed	$X_{employee}$	$\frac{1}{1}=1$
3.	Payment ratio	$\frac{\text{The salary of the upper 10\% of employees}}{\text{The salary of the lower 10\% of employees}}$	$R_{payment}$	$\frac{EUR}{EUR}=1$
4.	Fraction of workers satisfied with their work	$\frac{\text{Number of employees satisfied with their work}}{\text{Total number of employees}}$	$X_{satisf.}$	$\frac{1}{1}=1$
5.	Promotion rate[a]	$\frac{\text{Number of promotions}}{\text{Total number employed}}$	$R_{promot.}$	$\frac{1}{1}=1$
6.	Time of employee illness	Time of lost workdays because of injuries and illnesses	$t_{illness}$	days
7.	Fraction of charitable contributions	$\frac{\text{Charitable contributions to the community}}{\text{Total revenues}}$	$X_{contrib.}$	$\frac{EUR}{EUR}=1$
8.	Number of community projects	Number of projects of the company with its community	$N_{cooper.}$	1
9.	Mass fraction of local consumption	$\frac{\text{Mass of locally consumed products}}{\text{Total output mass of products}}$	$w_{loc.\ cons.}$	$\frac{kg}{kg}=1$
10.	Index of community population growth	Population growth in the community in %	$r_{com.\ pop.}$	1
2. Environmental indicators > 2.1 Input indicators > 2.1.1 Energy use indicators				
1.	Total energy consumption[b]	Total energy consumed	$E_{tot.}$	J
2.	Specific energy consumption	$\frac{\text{Total energy consumed}}{\text{Production output}}$	$E_{spec.}$	$\frac{J}{UP}$
3.	(Source of energy) fraction	$\frac{\text{Consumption per source of energy}}{\text{Total energy consumption}}$	E_{source}	$\frac{J}{J}=1$
4.	(Renewable energy) fraction	$\frac{\text{Renewable energy consumption}}{\text{Total energy consumption}}$	$E_{renew.}$	$\frac{J}{J}=1$
5.	Energy for recycling	Energy used for recycling	$E_{recycl.}$	J
6.	Energy intensity[c]	$\frac{\text{Total energy consumed}}{\text{Value of product sold or Value added}}$	$E_{intensity}$	$\frac{J}{EUR}$
7.	Total energy costs[b]	Absolute	$C_{E,\ tot.}$	EUR
8.	(Energy costs) fraction	$\frac{\text{Total energy costs}}{\text{Total production costs}}$	$C_{E,\ spec.}$	$\frac{EUR}{EUR}=1$
9.	Average costs of energy source	$\frac{\text{Costs per source of energy}}{\text{Consumption per source of energy}}$	$C_{E,\ source}$	$\frac{EUR}{J}$
2. Environmental indicators > 2.1 Input indicators > 2.1.2 Materials use indicators				
1.	Total material consumption[d]	Absolute mass	$m_{mat.,\ tot.}$	kg
2.	Specific material consumption	$\frac{\text{(Total material input) mass}}{\text{Production output}}$	$m_{mat.,\ spec.}$	$\frac{kg}{UP}$
3.	Fraction of renewable raw materials[b]	$\frac{\text{(Renewable raw material input) mass}}{\text{(Total material input) mass}}$	$w_{renw.\ mat.}$	$\frac{kg}{kg}=1$
4.	Raw materials efficiency[b]	$\frac{\text{(Production output) mass}}{\text{(Raw materials input) mass}}$	$\eta_{raw\ mat.}$	$\frac{kg}{kg}=1$
5.	Recycled material fraction[e]	$\frac{\text{(Recycled material input) mass}}{\text{(Total material input) mass}}$	$w_{recycl.\ mat.}$	$\frac{kg}{kg}=1$
6.	Variety of hazardous materials[b]	Number	$N_{haz.\ mat.}$	1
7.	Hazardous materials input mass[b]	Absolute mass	$m_{haz.\ mat.}$	kg
8.	Total material costs[b]	Absolute value	$C_{mat.,\ tot.}$	EUR
9.	Material intensity[c]	$\frac{\text{(Total material input) mass}}{\text{Value of product sold or Value added}}$	$I_{mat.}$	$\frac{kg}{EUR}$
2. Environmental indicators > 2.1 Input indicators > 2.1.3 Water use indicators				
1.	Total water consumption[b]	Absolute volume	$V_{water,\ tot.}$	m^3
2.	Specific water consumption	$\frac{\text{Water consumption volume}}{\text{Production output}}$	$V_{water,\ spec.}$	$\frac{m^3}{UP}$
3.	Volume fraction of water type[b]	$\frac{\text{Consumption volume per type of water}}{\text{Total consumption volume}}$	$\phi_{water\ type}$	$\frac{m^3}{m^3}=1$
4.	Total water costs[b]	Absolute value	$C_{water,\ tot.}$	EUR
5.	Water cost fraction[b]	$\frac{\text{Water costs}}{\text{Total production costs}}$	$C_{water,\ spec.}$	$\frac{EUR}{EUR}=1$
6.	Volume water type cost	$\frac{\text{Costs per type of water}}{\text{Consumption volume per type of water}}$	$C_{water\ type}$	$\frac{EUR}{m^3}$

table 8 (cont)

Indicator	Quantity	Symbol	Unit
2. Environmental indicators > 2.2 Output indicators > 2.2.1 Product indicators			
1. Mass fraction of products with an environmental label[b]	$\frac{\text{Mass of products with environmental labels}}{\text{Total mass of products}}$	$w_{\text{EL prod.}}$	$\frac{kg}{kg} = 1$
2. Mass fraction of products from recyclable materials[b]	$\frac{\text{Mass of products from recyclable materials}}{\text{Total mass of products}}$	$w_{\text{recycl. prod.}}$	$\frac{kg}{kg} = 1$
3. Mass fraction of products designed for disassembly, reuse or recycling[d]	$\frac{\text{Mass of products designed for recovery}}{\text{Total mass of products}}$	$w_{\text{recov. prod.}}$	$\frac{kg}{kg} = 1$
4. Product durability[e]	Time of durability	$t_{\text{durability}}$	Days, d or years, a
5. Revenues from eco products[b]	Absolute value	REV	EUR
6. Revenue fraction of eco products[b]	$\frac{\text{Revenues from ecoproducts}}{\text{Total revenue}}$	$REV_{\text{eco prod.}}$	$\frac{EUR}{EUR} = 1$
7. Total packaging mass[b]	Absolute mass	$m_{\text{pack.}}$	kg
8. Packaging mass fraction of the product[b]	$\frac{\text{Packaging mass}}{\text{Total mass of products}}$	$w_{\text{pack.}}$	$\frac{kg}{kg} = 1$
9. Mass fraction of reusable packaging[b]	$\frac{\text{Reusable packaging mass}}{\text{Total packaging mass}}$	$w_{\text{reus. pack.}}$	$\frac{kg}{kg} = 1$
10. Packaging costs[b]	Absolute value	$C_{\text{pack.}}$	EUR
11. Specific packaging costs[b]	$\frac{\text{Packaging costs}}{\text{Production output}}$	$C_{\text{pack., spec.}}$	$\frac{EUR}{UP}$
2. Environmental indicators > 2.2 Output indicators > 2.2.2 Solid waste indicators			
1. Total solid waste mass[b]	Absolute mass	$m_{\text{s, tot.}}$	kg
2. Specific solid waste mass	$\frac{\text{Mass of specific type of solid waste}}{\text{Production output}}$	$m_{\text{s, spec.}}$	$\frac{kg}{UP}$
3. (Solid waste mass) for recovery[b]	Recovered solid waste mass absolute	$m_{\text{s, recov.}}$	kg
4. (Solid waste mass) for disposal[b]	Non-recovered solid waste mass absolute	$m_{\text{s, disp.}}$	kg
5. Recycling mass fraction	$\frac{\text{Recycled solid waste mass}}{\text{Total mass of solid waste}}$	$w_{\text{s, recycl.}}$	$\frac{kg}{kg} = 1$
6. Disposal mass fraction[b]	$\frac{\text{Mass of non-recovered solid waste}}{\text{Total mass of solid waste}}$	$w_{\text{s, non-recycl.}}$	$\frac{kg}{kg} = 1$
7. (Hazardous solid waste) mass fraction[b]	$\frac{\text{Mass of hazardous solid waste}}{\text{Total mass of solid waste}}$	$w_{\text{s, haz.}}$	$\frac{kg}{kg} = 1$
8. (Hazardous solid waste) mass[b]	Mass of hazardous solid waste released into the environment	$m_{\text{s, haz.}}$	kg
9. Total solid waste costs[b]	Absolute value	$C_{\text{s, tot.}}$	EUR
10. Solid waste cost fraction[b]	$\frac{\text{Total solid waste costs}}{\text{Total production costs}}$	$C_{\text{s, spec.}}$	$\frac{EUR}{EUR} = 1$
2. Environmental indicators > 2.2 Output indicators > 2.2.3 Liquid waste indicators			
1. Total volume of liquid waste[b]	Absolute volume	$V_{\text{l, tot.}}$	m^3
2. Specific liquid waste volume	$\frac{\text{Total volume of liquid waste}}{\text{Production output}}$	$V_{\text{l, spec.}}$	$\frac{m^3}{UP}$
3. Non-polluted liquid waste volume[b]	Absolute volume	$V_{\text{l, non-poll.}}$	m^3
4. Polluted liquid waste volume[b]	Absolute volume	$V_{\text{l, poll.}}$	m^3
5. Specific pollution mass ratio[b]	$\frac{\text{Pollution load mass (e.g. P, N, AOX,...)}}{\text{Production output}}$	$R_{\text{poll., spec.}}$	$\frac{kg}{UP}$
6. Pollution mass concentration in liquid waste[b]	$\frac{\text{Mass of pollutants}}{\text{Liquid waste volume}}$	$c_{\text{l, poll.}}$	$\frac{kg}{m^3}$
7. Total liquid waste costs[b]	Absolute value	$C_{\text{l, tot.}}$	EUR
8. (Liquid waste) cost fraction[b]	$\frac{\text{Total liquid waste costs}}{\text{Total production costs}}$	$C_{\text{l, spec.}}$	$\frac{EUR}{EUR} = 1$
2. Environmental indicators > 2.2 Output indicators > 2.2.4 Air emissions indicators			
1. Mass fraction of greenhouse gases[c]	$\frac{\text{Total mass of } CO_2 \text{ equivalents}}{\text{Total mass of products}}$	$w_{CO_2\text{equiv.}}$	$\frac{kg}{kg} = 1$
2. Greenhouse gases intensity	$\frac{\text{Total mass of } CO_2 \text{ equivalents}}{\text{Value of product sold or Value added}}$	I_{GHGs}	$\frac{kg}{EUR}$
3. Acidification mass fraction[d]	$\frac{\text{Total mass of } SO_2 \text{ equivalents}}{\text{Total mass of products}}$	$w_{SO_2\text{equiv.}}$	$\frac{kg}{kg} = 1$

table 8 (cont) 1. Indicators of sustainable production (Krajnc and Glavic, 2003)

Indicator		Quantity	Symbol	Unit
4.	Acidification mass intensity	$\frac{\text{Total mass of } SO_2 \text{ equivalents}}{\text{Value of product sold or Value added}}$	$I_{acidif.}$	$\frac{kg}{EUR}$
5.	Photochemical ozone creating potential mass fraction[c]	$\frac{\text{Total mass of ethylene equivalents}}{\text{Total mass of products}}$	$w_{C_2H_4 equiv.}$	$\frac{kg}{kg} = 1$
6.	Photochemical ozone creating potential mass intensity[c]	$\frac{\text{Total mass of ethylene equivalents}}{\text{Value of product sold or Value added}}$	I_{POCP}	$\frac{kg}{EUR}$
7.	Eutrophication mass fraction	$\frac{\text{Total mass of phosphate equivalents}}{\text{Total mass of products}}$	$w_{PO_4^{3} equiv.}$	$\frac{kg}{kg} = 1$
8.	Eutrophication mass intensity	$\frac{\text{Total mass of phosphate equivalents}}{\text{Value of product sold or Value added}}$	$I_{eutroph.}$	$\frac{kg}{EUR}$
9.	Costs of purifying air[b]	Absolute value	$C_{pur.\ air}$	EUR
10.	Costs fraction of purifying air[b]	$\frac{\text{Absolute purifying cost}}{\text{Total production costs}}$	$C_{pur.\ air,\ fract.}$	$\frac{EUR}{EUR} = 1$
3. Economic indicators > 3.1 Financial indicators				
1.	Fraction of value added in GDP	Value added/GDP	$GDP_{contrib.}$	$\frac{EUR}{EUR} = 1$
2.	Value of investments in sustainable development	Investments in sustainable R&D as fraction of the expenses of the company	I_{SD}	EUR
3.	Value of investments in environmental protection	Investments of company in environmental protection	$I_{environment}$	EUR
4.	Environmental responsibility costs	Costs in case of environmental damage responsibility	$C_{env.\ resp.}$	EUR
5.	Specific number of complaints of customers	$\frac{\text{Number of complaints}}{\text{Mass of products sold}}$	$n_{complaints}$	$\frac{1}{kg}$
6.	Value fraction of investments in ethical activity	A profit invested in ethical business activities	$f_{ethic.\ act.}$	$\frac{EUR}{EUR} = 1$
7.	Number of sustainable environmental reports	Yearly number of positive/negative paper reports on environmental and social activity of the company	$N_{reports}$	1
8.	Number fraction of suppliers	Fraction of suppliers without environmental, health and safety violations	$R_{sup.,\ unprobl.}$	1
9.	Number of contact breaks	Number of contract breaks with suppliers because of disagreement with environmental, health and safety standards	$N_{contr.\ breaks}$	1
3. Economic indicators > 3.2 Employees indicators				
1.	Cost of employee	Cost of employee per production output	$C_{employee}$	EUR/UP
2.	Employee labor service duration	Average period of employee labor service	t_{labor}	a
3.	Costs of health protection of employee	Total costs of health protection of employee	C_{health}	EUR
4.	Noise level	Level of sound pressure at the working stations	L_{noise}	dB
5.	Investments in employee development	Investments in employee's education and professional/personal development	$I_{educ.}$	EUR
6.	Time of employee education	Average time of education per employee	$t_{educ.}$	h
7.	Number of suggested improvements by employee	Number of suggested improvements in quality, social, environmental, health and safety aspect of production per employee	$N_{sug.\ improv.}$	1

[a](IChemE),[b](FEM and FEA 1997),[c](AIChE),[d](Veleva and Ellenbecker 2001),[e](Azapagic and Perdan 2000).

NIST's (Japan National Institute of Science and Technology Policy) indicator categorization is based on five dimensions of sustainability:

1. environmental stewardship,
2. economic growth,
3. social well-being,
4. technological advancement,
5. and performance management.

Figure 10 shows the top-level categorization and the first level subcategorization:

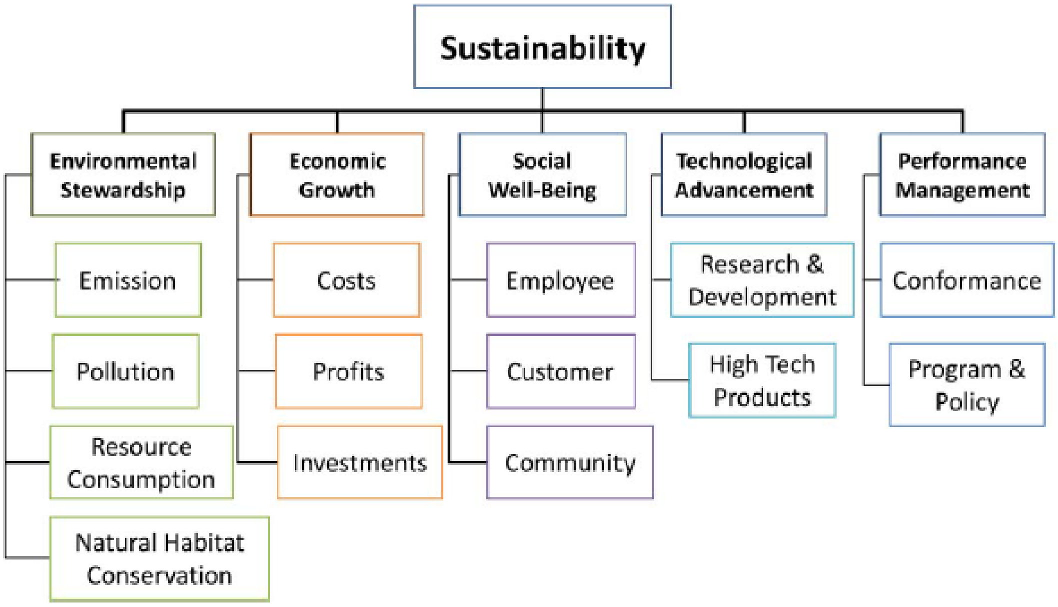


Figure 10. NIST sustainable indicator categorization. (Che B. Joung et al., 2012).

As can be seen the NIST indicators organization includes the three TBL dimensions and two other, namely :

1. technological advancement and
2. performance management.

Each class covers a different set of indicators (Che B. Joung et al., 2012):

The environmental stewardship covers environmental impacts from emissions, resource use, and ecosystem detriment from manufacturing processes and products.

The economic growth dimension emphasizes costs, profits, and benefits accrued along with investments made by the manufacturing organization.

Social well-being considers the impacts on employees, customers, and the community from health and safety programs, satisfaction assessments, and career/educational development.

Technological advancement accounts for the ability of a manufacturer to promote technological advancement through R&D staffing, expenditures, and high-tech products.

Performance management concerns deployment of sustainability programs and policies and conformance to regulations. Placement of indicators from the various sets was made according to the meaning and relevance of the given indicator based on a neutral definition.

With the selection, development, and placement of indicators in the structure of categorization, the result of the categorization shows an extensive collection of indicators that meet the overall concept of sustainable manufacturing. Further detail of this structure and the indicators within this structure can be found at the NIST's Sustainable Manufacturing Indicator Repository (SMIR) website:(http://www.mel.nist.gov/msid/SMIR/Indicator_Repository.html). The total number of indicators included within the SMIR is 212. Of the current indicators, 77 indicators belong to the environmental stewardship dimension, 23 to the economic growth dimension, 70 to the social well-being dimension, 30 to the performance management, and 12 to the technological advancement management. Examples of each dimension are in Table 9 .

Table 9.Indicator examples of each dimension of sustainability repository (NIST).

Dimension of sustainability	Name of the indicator	Definition	Unit	Placement	identifier
Environmental stewardship	Waste water amount	Amount of waste water discharged by an organization or process specified by category (i.e. eco-toxic, hazardous, treated, non-treated, reused, non ecotoxic, etc.)	Volume of total waste water discharged by an organization or process categorized by type	GRI-Emissions, effluents, and waste; GM MSM-Waste Management; ISO 14031-Operational performance indicators: Effluents to land/water	Env-17a
Economic growth	Profits generated	Total net profits for an organization or product	Dollar value of profits generated by an organization or product	UN-CSD	Eco-6d
Social well-being	Lost workdays	Workdays missed due to accidents	Number or percent of workdays missed due to accidents	GRI-Labor Practices: Occupational Health and Safety; GM MSM-Occupational Safety	Soc-1b
Technological advancement	Product output	Throughput for a specific product	Number of a specific product produced in a period	NISTEP	Tech-7a
Performance management	Environment incident response time	Time to respond to or correct environmental incidents	Time to respond to or correct environmental incidents	ISO 14031-Management performance indicators: Conformance	Per-2c

Another important aspect of indicators' characterizations is the measuring dimensions to which they refer. Damjan Krajnc (2003), identify four, namely unit of measurement, type of measurement, boundaries and period of tracking and calculating, as show in the Figure 11. Type of measurement refers, to quantitative or qualitative measurement, boundaries refer how far a company wishes to go in measuring the indicator, period of tracking and calculating refer to the default time interval in which we establish the measures, and units of measurements (kg, tones, volume etc).

To make a correct classification of indicators, it is important to identify a period for tracking and calculating the indicator (e.g. fiscal year, calendar year, 6 months, quarter, month) and define units of measurement (Krajnc and Glavic,2003). We must also identify a type of measurement (absolute or adjusted) and boundaries, which determine how far a company wishes to go in measuring the indicator.

Figure 11. Main dimensions of an indicator. Damjan Krajnc (2003)

3.6. Lowell Center for Sustainability Production

Vesela Veleva and Michael Ellenbecker (2001) propose an indicator framework developed at the Lowell Center for Sustainable Production (LCSP), University of Massachusetts Lowell and a methodology for developing and implementing indicators of sustainable production (ISPs), based on using core and supplemental indicators. Each core indicator is provided with a detailed guidance, and quantitative data for indicator calculation.

The LCSP framework emphasizes six main aspects or dimensions of sustainable production:

- energy and material use (resources)
- natural environment (sinks)
- social justice and community development
- economic performance
- workers
- products

Companies that wish to become more sustainable in their everyday practices should aim to address each of these six aspects. To promote better understanding of sustainable production among companies, the LCSP has also formulated nine guiding principles in which the indicator framework is based:

1) Products and packaging are designed to be safe and ecologically sound throughout their life cycles; services are designed to be safe and ecologically sound.
2) Wastes and ecologically incompatible by products are continuously reduced, eliminated, or recycled.
3) Energy and materials are conserved, and the forms of energy and materials used are most appropriate for the desired ends.
4) Chemical substances, physical agents, technologies, and work practices that present hazards to human health or the environment are continuously reduced or eliminated.
5) Workplaces are designed to minimize or eliminate physical, chemical, biological, and ergonomic hazards.
6) Management is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance of the firm.
7) Work is organized to conserve and enhance the efficiency and creativity of employees.

8) The security and well-being of all employees is a priority, as is the continuous development of their talents and capacities.
9) The communities around workplaces are respected and enhanced economically, socially, culturally and physically; equity and fairness are promoted.

The LCSP indicator framework is organized in five levels, Figure 12.

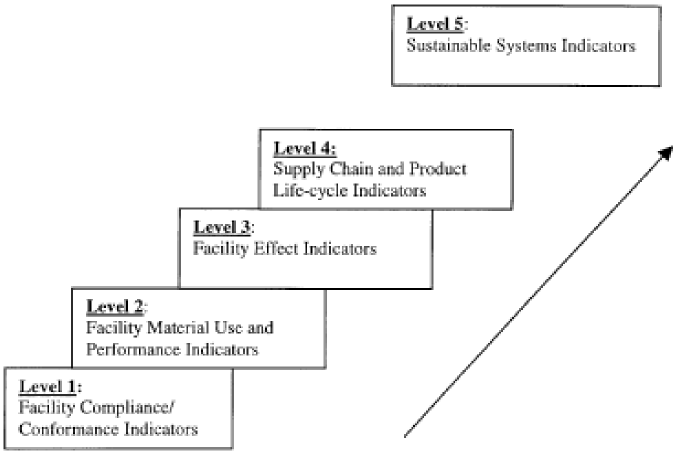


Figure 12. Lowell Center for Sustainable Production indicator framework. Vesela Veleva and Michael Ellenbecker (2001).

Level 1 is concerned with companies complyance with regulations and industry standards. Level 2 says that It will always be important that companies monitor their efficiency and productivity. Level 3 indicators measure potential effects of a company/facility on environmental, worker and public health, community development and economic performance (e.g., global warming potential, percent of workers with work-related disease). Level 4 indicators measure company/facility production impacts looking at the supply chain as well as product distribution, use and ultimate disposal (e.g., percent of products designed for disassembly). Level 5 indicators show how an individual company's production process fits into the larger picture of a sustainable society.

LCSP methodology is based on core indicators and supplemental indicators of sustainable production. There are 22 core indicators, and the goal of these indicators is built on the work of other groups and organizations, such as GRI, World Business Council for Sustainable Development WBCSD, Center for Waste Reduction Technologies CWRT, and ISO 14031, providing a detailed guidance on indicator calculation and how to use.

The twenty-two core indicators are organized in six sections to address the six aspects of sustainable production above mentioned, Table 10. Each section includes the respective LCSP principles of sustainable production that serve as a basis for selecting goals and indicators. Units of measurement and sustainability level are provided for each indicator but these may vary, depending on the organization's choice of indicator dimensions (e.g., unit of measurement, boundaries). It is recommended that both total and production- adjusted amounts be calculated (e.g., "total energy use" and "energy use per unit of product").

Table 10. Core indicators of LCSP sustainable method (Veleva and Ellenbecker, 2001)

Aspect of SP	LCSP principle	Generic goal	Indicator	Metric	Level
1. Energy and material use	*Principle #3*: Energy and materials are conserved, and the form of energy and materials used are most appropriate for the desired ends.	*Goal*: Reduce the use of fresh water.	(1) Fresh water consumption	liters	Level 2
		Goal: Reduce material use.	(2) Materials used (total and per unit of product).	kg	Level 2
		Goal: Reduce energy use.	(3) Energy use (total and per unit of product)	kWh	Level 2
		Goal: Increase the use of energy from renewable sources.	(4) Percent energy from renewables.	%	Level 2
2. Natural environment (including human health)	*Principle #2*: Wastes and ecologically incompatible byproducts are continuously reduced, eliminated or recycled.	*Goal*: Reduce the amount of waste generated before recycling (air, water, and land).	(5) Kilograms of waste generated before recycling (emissions, solid and liquid waste).	kg	Level 2
	Principle #4: Chemical substances, physical agents, technologies, and work practices that present hazards to human health or the environment are continuously reduced or eliminated.	*Goal*: Reduce greenhouse gas emissions.	(6) Global warming potential (GWP).	Tons of CO_2 equivalent	Level 3
		Goal: Reduce emissions of acid gasses	(7) Acidification potential.	Tons of SO_2 equivalent	Level 3
		Goal: Phase out all PBT chemicals.	(8) kg of PBT chemicals used.	kg	Level 3
3. Economic performance	*Principle #6*: Management is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance of the firm.	*Goal*: Reduce EHS compliance costs.	(9) Costs associated with EHS compliance (e.g., fines, liabilities, worker compensation, waste treatment and disposal, remediation).	$	Level 1
		Goal: Zero customer complaints or returns.	(10) Rate of customer complaints and returns.	Number of complaints/returns per product sale	Level 2
		Goal: Increase stakeholder involvement in decision-making.	(11) Organization's openness to stakeholder review and participation in decision-making process (scale 1–5).	Number (1–5)	Level 2
4. Community development and social justice.	*Principle #9*: The communities around workplaces are respected and enhanced economically, socially, culturally and physically; equity and fairness are promoted.	*Goal*: Increase community spending and charitable contributions.	(12) Community spending and charitable contributions as percent of revenues.	%	Level 2
		Goal: Increase employment opportunities for the local community.	(13) Number of employees per unit of product or dollar sales.	Number/$	Level 2
		Goal: Increase community–company partnerships.	(14) Number of community–company partnerships.	#	Level 2
5. Workers	*Principle #5*: Workplaces are designed to continuously minimize or eliminate physical, chemical, biological, and ergonomic hazards.	*Goal*: Achieve zero lost workdays as result of work-related injuries and illnesses.	(15) Lost workday injury and illness case rate (LWDII).	Rate	Level 2
	Principle #7: Work is organized to conserve and enhance the efficiency and creativity of employees.	*Goal*: Increase the rate of employee suggested improvements in quality, social and EHS performance.	(16) Rate of employees' suggested improvements in quality, social and EHS performance.	Number of suggestions per employee	Level 2
	Principle #8: The security and well-being of all employees is a priority, as is the continuous development of their talents and capacities.	*Goal*: Reduce turnover rate	(17) Turnover rate or average length of service of employees.	Rate (years)	Level 2
		Goal: Increase employee training.	(18) Average number of hours of employee training per year.	Hours	Level 2
		Goal: Increase employee well-being and job satisfaction.	(19) Percent of workers, who report complete job satisfaction (based on questionnaire).	%	Level 3
6. Products	*Principle #1*: Products and packaging are designed to be safe and ecologically sound throughout their life cycle; services are designed to be safe and ecologically sound.	*Goal*: Design all products so that they can be disassembled, reused or recycled.	(20) Percent of products designed for disassembly, reuse or recycling.	%	Level 4
		Goal: Use 100% biodegradable packaging.	(21) Percent of biodegradable packaging.	%	Level 4
		Goal: Increase percent of products with take-back policies.	(22) Percent of products with take-back policies in place.	%	Level 4

For example, the fresh water consumption indicator, which has the goal of reducing the use of fresh water, measured in litters, fits in the level 2, and the principle is the number #3.

There are also supplemental indicators, organized in accordance to the LCSP five-level framework and the six aspects of sustainable production, and can be used as a guide for developing and using higher level, more complex ISPs.

To implement sustainable indicators an eight-step continuous-loop model for defining and measuring sustainability performance of companies was developed and is presented on Figure 13. It is based on a model, developed by Bennett (1999) to define and evaluate environment-related performance.

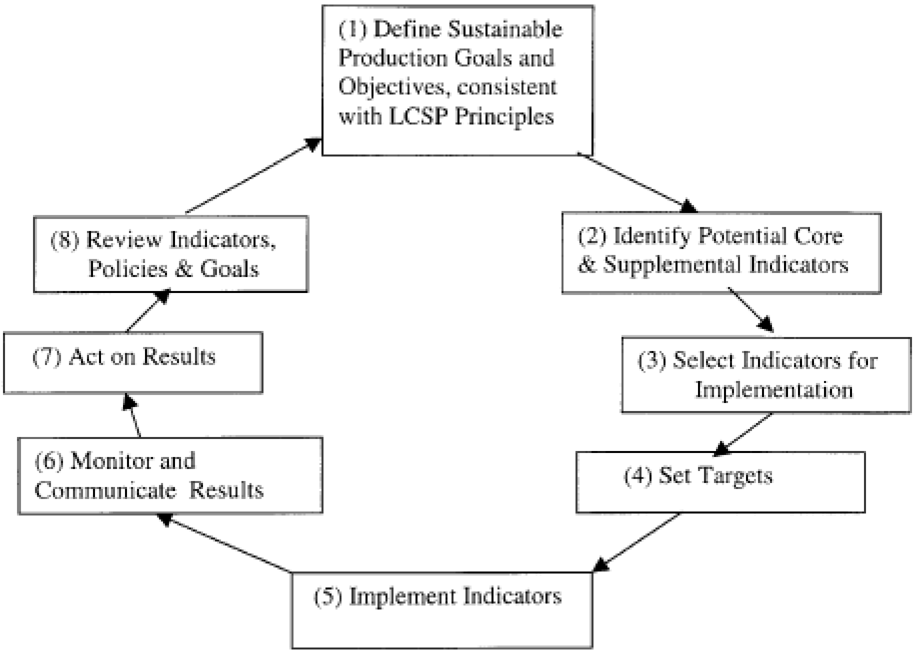


Figure 13. Continuous-loop model for defining and measuring sustainability performance of organizations. Vesela Veleva and Michael Ellenbecker (2001).

Each step is explained below:

- The *first step* involves defining sustainable production goals and objectives that are consistent with LCSP principles. These goals and objectives may reflect a company's mission.
- The *second step* involves identification of potential indicators to reflect a company's goals and targets toward sustainable production. It is recommended that a company use all core indicators.
- The *third step* in the model includes selection of indicators for implementation. In addition to the core indicators, companies/facilities are encouraged to consider additional, production-specific indicators.
- *Four step* is to set targets. Is a key step, where management (after consultation with stakeholders) sets specific goals. This step is important, since it ensures management commitment and promotes accountability.
- *Step five* is indicator implementation. It is a key step that involves data collection, calculation, evaluation and interpretation of results. This is the most time-consuming step and requires wide participation of an organization's personnel, in particular the middle management.
- *Step six* involves monitoring and communicating results. For continuous improvement to occur, an organization needs periodically to communicate and evaluate results from indicator use.
- Acting on results *(step 7)* is a critical step in the process of indicator use. Here management takes corrective measures and demonstrates that ISPs are not simply a "public relations exercise" but rather a process of continuous improvement of an organization's environmental, occupational and social performance.

- The last step (step 8) includes review of indicators, policies and goals. This is a key step, since it lays the grounds for setting new goals, objectives and indicators.

Finally Vesela Veleva and Michael Ellenbecker expose strengths and weakness of this methodology. Some of the strengths are that includes quantitative and qualitative indicators, provides detailed guidance on how to use etc. Some weakness are, for example, no detailed guidance is provided on how to construct and calculate supplemental indicators, or although the goal is to suggest simple and easy to implement indicators, some organizations may still find these difficult to use.

3.7. Global Reporting Initiative (GRI)

Global Reporting Initiative (GRI) was launched by The United Nations Environment Programme (UNEP) in association with the United States nongovernmental organization, Coalition for Environmentally Responsible Economics (CERES), in 1997 for improving the quality, structure and coverage of sustainability reporting (Labuschagnea et al. 2005). Sustainability Reporting is the focal point of the guidelines (now goes by the fourth guideline-G4-presented on May 2013). The GRI uses sustainability reporting on three dimensions viz. social, economic, and environmental as shows Figure 14. It is applicable to organizations of any size or type, and from any sector or geographic region, and has been used by thousands of organizations worldwide as the basis for their sustainability reporting. More than 4.000 organizations from 60 countries use the Guidelines to produce their sustainability reports.

It facilitates transparency and accountability by organizations and provides stakeholders a universally-applicable, comparable framework from which to understand disclosed information.

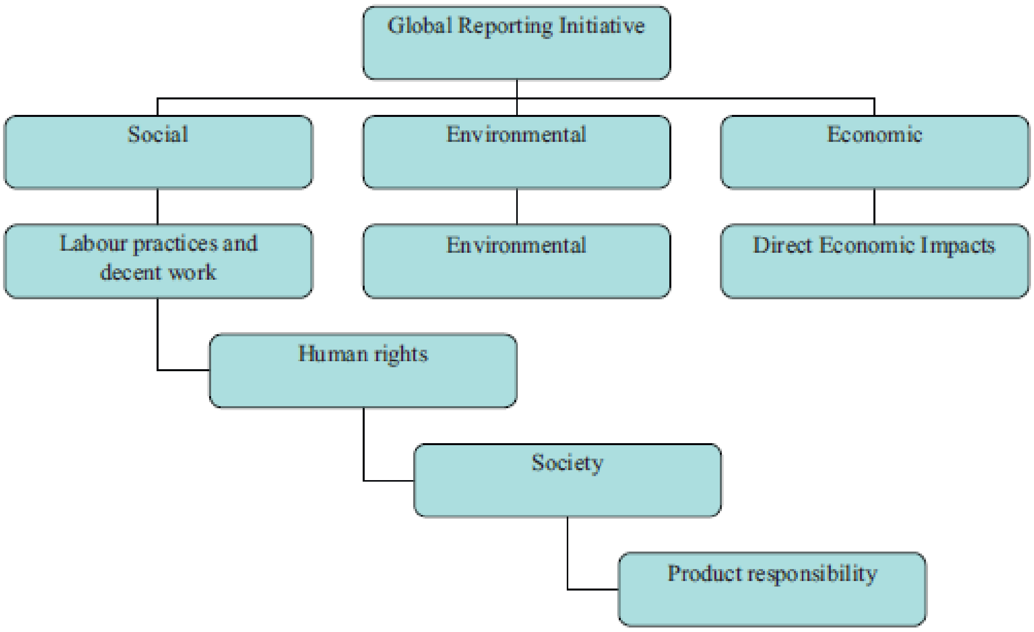


Figure 14. The hierarchical structure of the global reporting initiative (GRI) framework. www.globalreporting.org

GRI has Reporting Principles that are fundamental to achieving transparency in sustainability reporting and therefore should be applied by all organizations when preparing a sustainability report.

The Principles are divided into two groups: Principles for Defining Report Content and Principles for Defining Report Quality.

The Principles for Defining Report Content describe the process to be applied to identify what content the report should cover by considering the organization's activities, impacts, and the substantive expectations and interests of its stakeholders.

The Principles for Defining Report Quality guide choices on ensuring the quality of information in the sustainability report, including its proper presentation. The quality of the information is important to enable stakeholders to make sound and reasonable assessments of performance, and take appropriate actions.

The Principles for Defining Report Content are:

- **Stakeholder Inclusiveness**: The organization should identify its stakeholders, and explain how it has responded to their reasonable expectations and interests.
- **Sustainability Context**: The report should present the organization's performance in the wider context of sustainability.
- **Materiality:** The report should cover Aspects that:
  - Reflect the organization's significant economic, environmental and social impacts.
  - Substantively influence the assessments and decisions of stakeholders.
- **Completeness:** The report should include coverage of material Aspects and their Boundaries, sufficient to reflect significant economic, environmental and social impacts, and to enable stakeholders to assess the organization's performance in the reporting period.

The Principles for Defining Report Quality are:

- **Balance**: The report should reflect positive and negative aspects of the organization's performance to enable a reasoned assessment of overall performance.
- **Comparability**: The organization should select, compile and report information consistently. The reported information should be presented in a manner that enables stakeholders to analyze changes in the organization's performance over time, and that could support analysis relative to other organizations.
- **Accuracy**: The reported information should be sufficiently accurate and detailed for stakeholders to assess the organization's performance.
- **Timeliness:** The organization should report on a regular schedule so that information is available in time for stakeholders to make informed decisions.
- **Clarity**: The organization should make information available in a manner that is understandable and accessible to stakeholders using the report.

- **Reliability**: The organization should gather, record, compile, analyze and disclose information and processes used in the preparation of a report in a way that they can be subject to examination and that establishes the quality and materiality of the information.

GRI in the last version-G4- is presented in a format that has two parts: **The GRI Sustainability Reporting Guidelines** (the Guidelines) offer Reporting Principles, Standard Disclosures and an **Implementation Manual** for the preparation of sustainability reports by organizations, regardless of their size, sector or location (web site [6]). The Guidelines also offer an international reference for all those interested in the disclosure of governance approach and of the environmental, social and economic performance and impacts of organizations. The Guidelines are useful in the preparation of any type of document which requires such disclosure. The Guidelines have the following steps to prepare a sustainability report:

1. Obtain an overview reading the Reporting Principles and Standard Disclosures.
2. Choose the preferred 'in accordance' option: The Guidelines offer two options for an organization to prepare its sustainability report 'in accordance' with the Guidelines. The two options are Core and Comprehensive.
3. Prepare to disclose general standard disclosures: Identify the General Standard Disclosures required for the chosen 'in accordance' option. Check if there are General Standard Disclosures that apply to the organization's sector.
4. Prepare to disclose specific standard disclosures: Specific Standard Disclosures are Disclosures on Management Approach (DMA) and Indicators. They are presented under Categories and Aspects, as displayed in Table 11.
5. Prepare the sustainability report.

Table 11. Categories and aspects in the Guidelines. www.globalreporting.org

Category	Economic		Environmental	
Aspects[III]	• Economic Performance • Market Presence • Indirect Economic Impacts • Procurement Practices		• Materials • Energy • Water • Biodiversity • Emissions • Effluents and Waste • Products and Services • Compliance • Transport • Overall • Supplier Environmental Assessment • Environmental Grievance Mechanisms	
Category	**Social**			
Sub-Categories	**Labor Practices and Decent Work**	**Human Rights**	**Society**	**Product Responsibility**
Aspects[III]	• Employment • Labor/Management Relations • Occupational Health and Safety • Training and Education • Diversity and Equal Opportunity • Equal Remuneration for Women and Men • Supplier Assessment for Labor Practices • Labor Practices Grievance Mechanisms	• Investment • Non-discrimination • Freedom of Association and Collective Bargaining • Child Labor • Forced or Compulsory Labor • Security Practices • Indigenous Rights • Assessment • Supplier Human Rights Assessment • Human Rights Grievance Mechanisms	• Local Communities • Anti-corruption • Public Policy • Anti-competitive Behavior • Compliance • Supplier Assessment for Impacts on Society • Grievance Mechanisms for Impacts on Society	• Customer Health and Safety • Product and Service Labeling • Marketing Communications • Customer Privacy • Compliance

3.8. International organization for standardization ISO14031

The ISO 14031 standard, part of the ISO 14000 family of voluntary international environmental standards, provides guidance on the design and use of environmental performance evaluation (EPE) within an organisation. It applies to all organisations, regardless of type, size, location and complexity. Whereas the GRI framework focuses on indicators that are most relevant to the stakeholders, ISO 14031 makes no recommendations about reporting or about which indicators an organization should utilize –although it does include a list of 197 topics from which companies could select indicators for environmental management (Croci, 2006).

Following ISO 14031´s definition, environmental performance evaluation (EPE) is essentially an iterative process to facilitate management decisions regarding an organization´s environmental performance by going through three main stages:

1. Planning (management considerations and selecting environmental indicators);

2. Evaluation (collecting data; analysing and converting data; assessing information against environmental performance criteria; reporting and communicating);

3. Periodically reviewing and improving EPE.

ISO 14031 can thus be seen as being complementary to the GRI framework. We also draw attention to the similarity between the EPE stages and the previously discussed benchmarking phases and steps.

ISO 14031 describes two general categories of indicator for EPE: 1) Environmental Performance indicators (EPIs) and 2) Environmental Condition Indicators (ECIs). ECI is defined as a “specific expression that provides information about the local, regional, national or global condition of the environment”. EPIs are subdivided in Operational Performance Indicators (OPIs) and Management Performance Indicators (MPIs). The latter provide information about management efforts to influence the environmental performance of the organization´s operations, whereas the former provide information about the environmental performance itself. OPIs relate to inputs, outputs and the physical facilities and equipment of the organization. Energy (input) indicators clearly belong to the set of OPIs.

3.9. Others indicator frameworks

The United Nations Commission on Sustainable Development (CSD) devised a framework for monitoring the various sustainability indicators for assessing the performance of government towards sustainable development goals (Labuschagnea et al., 2005). The structure of framework comprises four dimensions viz. social, environment, economic and institutional and it is broken down into 38 sub-indicators and 15 main indicators (Figure 15) .

Another set of indicators formulated by The Institution of Chemical Engineers (IChemE) has also formulated a sustainability metrics framework covering the three typical dimensions: environment, economic and social (Labuschagnea et al., 2005). The metrics were developed to assess the sustainability performance of process industry, Figure 16.

The Wuppertal Institute also developed framework of sustainability by addressing the four dimensions of sustainable development, as defined by the United Nations CSD. These four aspects are linked through set of various indicators (Labuschagnea et al., 2005), Figure 17.

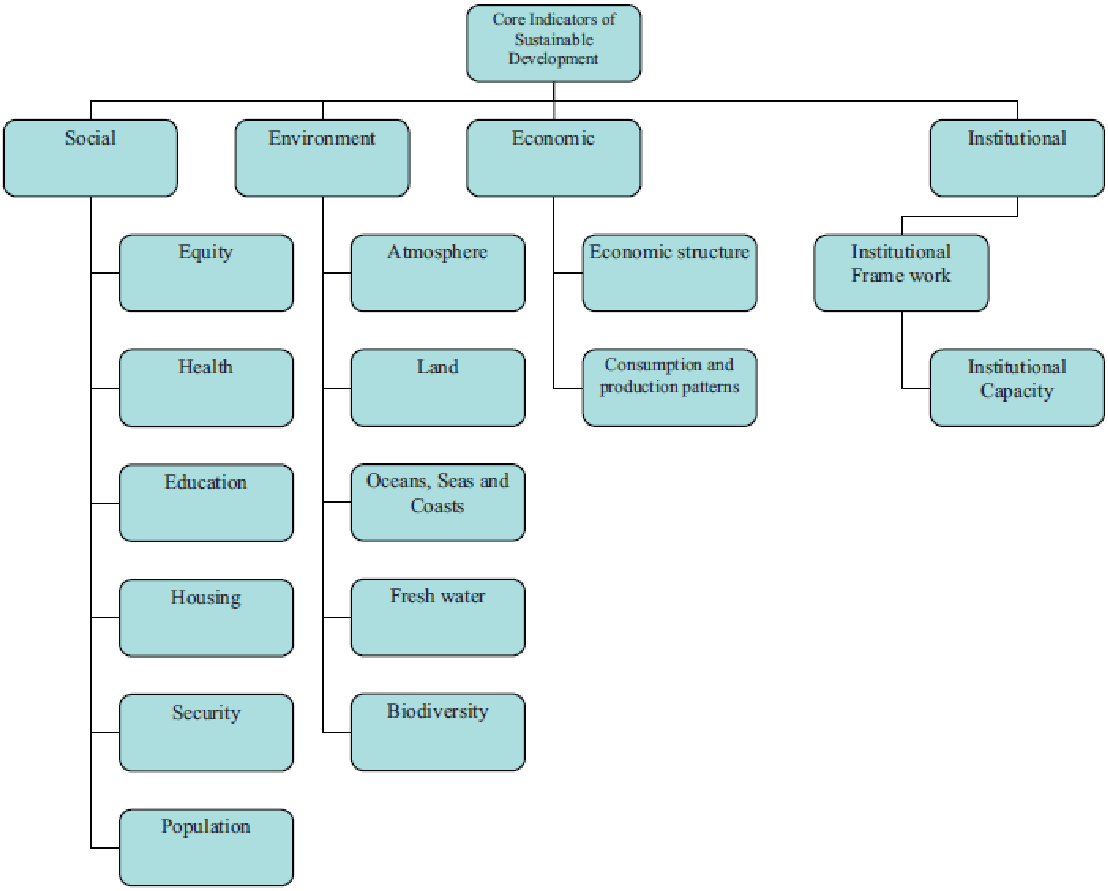


Figure 15. The United Nations Commission for Sustainable Development (UNCSD) theme indicator framework. Labuschagnea et al. (2005).

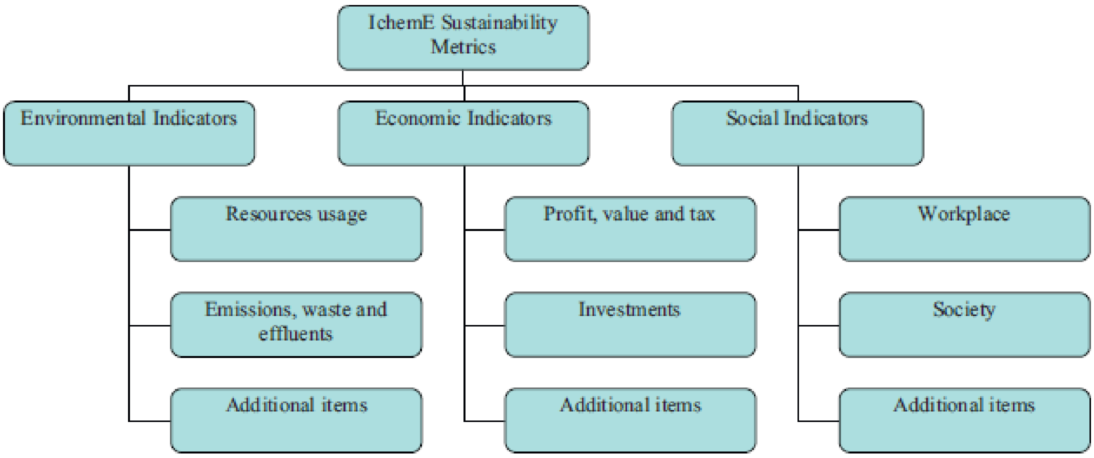


Figure 16. The Institute of Chemical Engineers (IChemE) sustainability metrics framework. Labuschagnea et al. (2005).

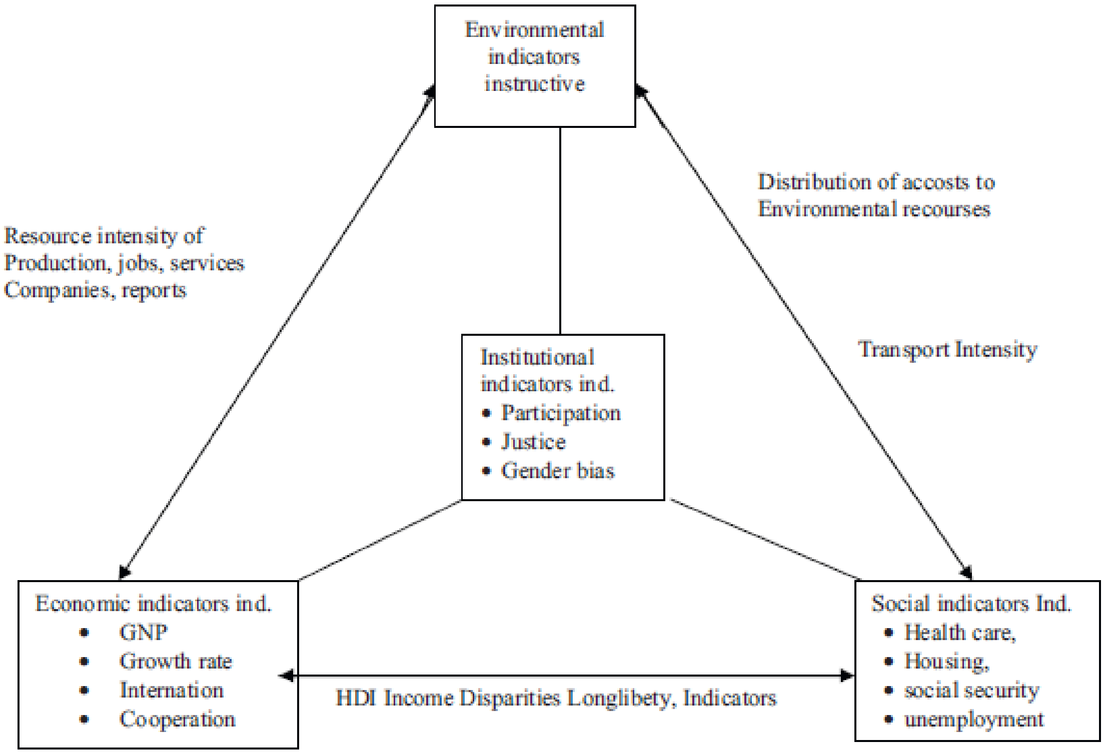


Figure 17. The Wuppertal sustainable development indicator framework. Labuschagnea et al. (2005).

4. Composite indicators

4.1. Introduction

Most companies have been using mostly standard financial indicators to track their business effectiveness. Nowadays, due to demands from various stakeholders, including customers, suppliers, employees, national regulators, banks, insurance companies, shareholders, trade associations and local communities, sustainability reports are emerging as a new trend in companies reporting, integrating into one report the elements of financial, environmental, and social facets of the company (GRI, 2002).

However, most indicator frameworks for sustainability evaluation do not use aggregate measures for easy evaluation and comparison of sustainability performance of companies. Despite the indicators developed, there is still no useful method for integrated sustainability assessment of companies. To meet the challenges of sustainability, an approach for integrated assessment of companies is required to provide a good guidance for decision-making (Krajnc and Glavic,2003). It is important that aggregation of indicators to sustainability indices could provide a chance for new policy guiding instruments and better integration of decision-making, as well as public participation in sustainability discussion. In fact, the common principle to aggregate indicators for assessment of the company has gained acceptance, but has also become evident that methods for the aggregation of indicators are either not sufficiently well established yet, or are under development, or are not available with respect to all the sustainability aspects(Krajnc and Glavic,2003).

As the credibility of aggregation methodologies is of crucial importance for the quality of new information categories, more research is needed on the aggregation methodologies and on the relevance of basic data for comprehensive assessments.

The construction of composite indicators involves selection of various methods/tools/techniques at different stages of development process. However, this may result in various issues of uncertainty due the selection of data, erroneous data, data imputation methods, data normalization, standardization, weighting methods, weight of values and aggregation methods (Kumar Singh et al, 2011).

Development of indices is considered to be a unique approach for evaluating sustainable development. Computing aggregate values is one of the common methods for constructing indices. Indices can be constructed with or without weights depending on its application. Indices are very useful in focusing attention and, often simplify the problem (Atkinson et al., 1997).

Some efforts to develop composite indicators have paid off in composite indicators like Sustainable Economic Index Function (EIF) (Ares et al. 2012) or Integrated Assessment of Sustainable Development (Krajnc and Glavic, 2003).

4.2. Economic and Functional Efficiency Index of a sustainable production line

Ares et al. (2012) proposes an Economic Index Function (EIF) for sustainable production. The purpose of this index is to constitute a tool of assist in the decision-making process at different levels of the company's hierarchy, related with the three TBL dimensions. The EIF is based on cost variables of three dimensions: production, environment and society, Figure 18. The function is expressed as:

sustainable EIF = production EIF + environmental EIF + social EIF.

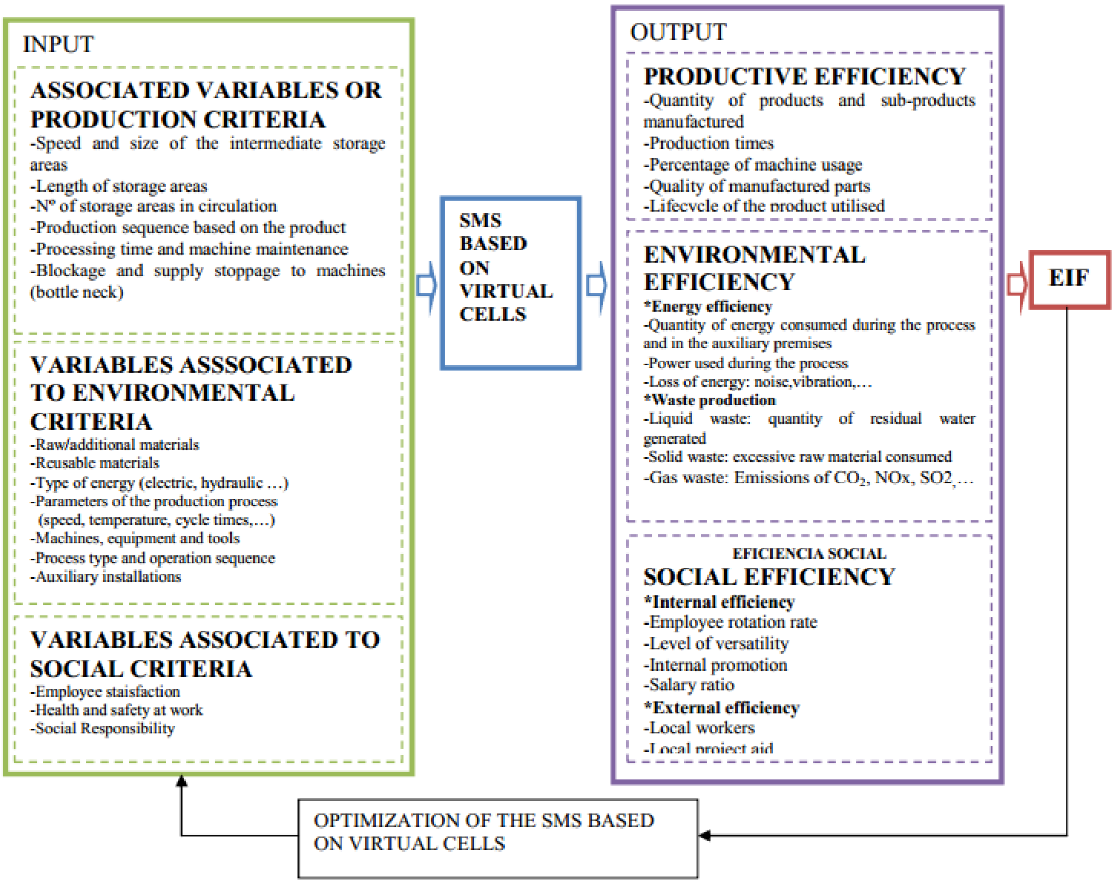


Figure 18. The Input and Output process of the sustainable manufacturing system SMS (Ares et al.2011).

The terms can be weighted, by α,β and γ, for differentiating the importance of each on an organization, in such a way that the function can be rewritten as:

EIF sustainable= α EIFp +β EIFe +γ EIFs.

4.2.1. Production dimension

Analysing each dimension of the EIF function, the first term, EIFp represents production costs of using production facilities, i.e. the workstations in the system. Table 12 summarizes the list of variables that are taken into account to determine the cost of EIFp in the sustainable economic index function.

Table 12. Variables of the production indicator.

VARIABLE	DESCRIPTION
Nij	Total number of i type parts produced on each machine j
n	Is a generic counter of the entities involved (machines, storages,workstations etc.)
TPij	Processing time of the i type part on machine j
CFij	Cost of manufacture of the i type part on machine j per time unit
CNUj	Cost of non-use of machine j per time unit
TIj	Time of inactivity of machine j
CPIPE	Penalisation costs due to the failure to meet delivery times
TAE	Period of delay in meeting the order
Bij	Total number of i type parts handled by each storage area or pallet j
TMij	Handling period of the i type part from machine j to machine j+1
CMij	Handling cost of i type part from machine j to machine j+1
CNUBj	Non-usage cost of storage area j per time unit
TIBj	Period of inactivity of storage area

The value of EIFp, can then be established for each part i manufactured in the production system, by:

EIFp= $\sum_{j=1}^{n} \mathrm{Nij}$ $*$TPij $*$CFij+$\sum_{j=1}^{n} \mathrm{CNUj}$ $*$TIj+CPIPE$*$ TAE+$\sum_{j=1}^{n} \mathrm{Bij}$ $*$TMij$*$ CMij+$\sum_{j=1}^{n} \mathrm{CNUBj}$ $*$ TIBij

This includes input and output measures.

4.2.2. Environmental dimension

The next term of the EIF function is the EIFe, which takes account of the environmental criteria and costs. This term uses data from inputs and outputs of the production system.

Inputs of the production system

- **Material:** Represent the amount of environment's relevant material used in production. Besides the most important raw materials, these indicators also include dangerous input materials to the environment or those for which the company need to have a close control based on target values. This allows optimization efforts that are focused on a manageable number of environmentally significant materials (Ex. Solvents, dangerous substances etc.). Over time, the environmental indicators help to control the replacement of problematic materials by safer alternatives to the environment (Ex. Renewable raw materials, replaceable packaging, recyclable raw materials, paints and varnishes without solvents). For collecting and aftertreatment data associated with this indicator should establish a unit type measure in Kg or Tm.

- **Energy**: An important indicator is the total energy consumption (of all energy consumption sources including equipment). In order to add or compare the data, we should use kilowatt hours (kWh) or megawatt hour (MWh). As natural gas is usually calculated in cubic meters (m3) and diesel fuel in liters (l) we have to convert these measures. Table 13 illustrates the most important weight conversion factors in kg or volume (in litters or m3) for input power sources in its energy value (kWh):

Table 13. . Input conversion factors

ENERGY CONVERSION FACTORS, in KWh		
Natural gas	10,00 kWh / m3	12,66 kWh / kg
Light diesel	9,93 kWh / l	11,68 kWh / kg
Weight diesel	10,27 kWh / l	11,17 kWh / kg
anthracite	—	8,14 kWh / kg
lignite	—	5,35 kWh / kg

- **Water**: The indicator of the total water consumption is determined for all types of water and all points of water consumption.

Outputs of the production system

- **Solid waste**: waste indicators are very important for environmental management, because prevention and recycling of waste accounts for environmental objectives with economic advantages. Starting point to set waste indicators is the total amount of measured waste in kilograms or tonnes, therefore will be listed in the European Waste Catalogue (EWC), approved by the Community Institutions. Total costs of waste are very interest, since reducing the amount of waste also means a significant reduction of all costs associated with them.

- **Air emissions**: Emissions to the atmosphere are especially important because diverse environmental impacts (ground pollution, greenhouse, etc.). The amounts of absolute toxic substances emitted can be used as basic indicators. Due to the variety of atmospheric emissions, the indicators should be restricted to the most relevant substances. These may include:

  - nitrogen oxide (NOx)
  - carbon dioxide (CO_2)
  - sulfur dioxide (SO_2)
  - particles
  - Volatile Organic Compounds (VOC)

  Selection of the important emission parameters must be made in function of the specific company activity and, if it was necessary, supplemented or replaced by other substances. Due to high costs involved, is not common for small and medium (SMEs) to make a direct measurement of emissions. A good method to obtain emissions data is calculate from inputs data and energy consumed. Using energy consumed data in KWh we can apply the follow conversion factors to calculating CO_2 combustion emissions in Table 14.

If CO_2 it's also generated in the production process, these values have to add them appropriely.

Table 14. Outputs conversion factors (Bundestag, 1994).

Emissions of CO2 per KWh of input	g/KWh of C02 energy
Natural gas	200
Weight diesel	280
Light diesel	260
External power supply electricity	492

- **Waste water**: total amount of waste water in cubic meters is obtained from the amount of all water flows pollutants and no pollutants discharged into the manifold or the drainage network. Besides illustrating quantitative flows in cubic meters, can be useful indicators for specific contaminated loads or concentrations of pollution.

Table 15 shows the list of variables that are in the environmental indicator of this index function:

Table 15. Variables of the emvironmental.

INDICATOR	CONCEPT	VARIABLES	DESCRIPTION
INPUT	MATERIALS	Mij	Total consumption of material for the production of a part (kg)
		CMij	Cost of material for the production of a part (€/Kg)
		Eij	Number of packages used in the production of a part (Kg)
		CEij	Cost of package disposal (€/Kg)
	ENERGY	PEij	Power of energy consumption (KWh)
		CPEz	Cost of the energy consumed for each section of line z (€/KWh)
	WATER	CAij	Water consumption (m^3)
		CCAz	Cost of the water consumed for each section of line z (€/m^3)
OUTPUTS	SOLID WASTE	Rij	Total amount of waste produced in the manufacture of a part (kg)
		CRij	Cost of disposal of solid waste (€/Kg)
	EMISSIONS	EAij	Amount of emissions discharged into the atmosphere(kg)
		CEAz	Cost of the depuration treatment of the emissions in each section of line z (€/Kg)

	RESIDUAL WATER	ARij	Total amount of waste water produced during the manufacture of a part (m^3)
		CARz	Cost of the depuration treatment of the water in each section of line z (€/m^3)

Thus the equations of environmental costs for inputs and outputs can be determined.

For **inputs** is:

$$\mathrm{EIFei} = \sum_{j=1}^{n} \mathrm{Mij} * \mathrm{CMij} + \sum_{j=1}^{n} \mathrm{Eij} * \mathrm{CEij} + \sum_{j=1}^{n} \mathrm{PEij} * \mathrm{CPEz} + \sum_{j=1}^{n} \mathrm{CAij} * \mathrm{CCAz}$$

The next function belongs the environmental outputs costs associated and for **outputs** is:.

$$\mathrm{EIFao} = \sum_{j=1}^{n} \mathrm{Rij} * \mathrm{CRij} + \sum_{j=1}^{n} \mathrm{EAij} * \mathrm{CEAz} + \sum_{j=1}^{n} \mathrm{ARij} * \mathrm{CARz}$$

from where the function for the **total** environmental costs become:

$$\mathrm{EIFe} = \sum_{j=1}^{n} \mathrm{Mij} * \mathrm{CMij} + \sum_{j=1}^{n} \mathrm{Eij} * \mathrm{CEij} + \sum_{j=1}^{n} \mathrm{PEij} * \mathrm{CPEz} + \sum_{j=1}^{n} \mathrm{CAij} * \mathrm{CCAz} + \sum_{j=1}^{n} \mathrm{Rij} * \mathrm{CRij} + \sum_{j=1}^{n} \mathrm{EAij} * \mathrm{CEAz} + \sum_{j=1}^{n} \mathrm{ARij} * \mathrm{CARz}$$

4.2.3. Social dimension

Finally, the last level is EIFs, associated for the social dimension. This function takes the CSR initiative guidelines to select important aspects and variables or indicators for evaluating the social dimension of sustainable production. Examples are versatility, accidents and prevention, equality of opportunities, categorized in an internal group related with employees, and selection of materials, product risks, complaints, categorized in an external group related with suppliers and customers. Table 16 gives a description of these variables.

Table 16. Type of stakeholder and its variable.

TYPE OF STAKEHOLDER		INDICATOR	VARIABLE	
INTERNAL	EMPLOYEE		NTj	Nº of workers on each machine j
		VERSATILITY	HFP	Nº of training hours for the post
			CHFP	Cost of the training hour for adaptation to the post (€/h)
		ACCIDENTS AND PREVENTION	HFC	Nº of training hours for safety and health
			CHFC	Cost of the training hour for safety and health (€/h)
			CMEPI	Cost associated to the maintenance and acquisition of the EPIs(€)

		EQUALITY OF OPPORTUNITIES	TIO	Time spent on drawing up and implementing a plan aimed at eliminating discrimination in the selection processes
			CPS	Cost per hour of the RR.HH. staff(€/h)
EXTERNAL	SUPPLIER	SELECTION OF MATERIALS	CNM	Cost associated with the choice of products to minimize environmental impact (€)
	CUSTOMER	PRODUCT RISKS	CIR	Costs associated to designing labels and clear instructions (€)
		COMPLAINTS	NQC	Nº of customer complaints and claims
			CQC	Cost associated to the resolution of the problem(€)

The term associated to the **internal** group of indicators is:

$$EIFsi = \sum_{j=1}^{n} NTj * HFP * CHFP + \sum_{j=1}^{n} NTj * HFC * CHFC + \sum_{j=1}^{n} NTj * CMEPI + \sum_{j=1}^{n} NTj\ (TIO * CPS)$$

and with the **external** one is:

$$EIFse = \sum_{j=1}^{n} CIR + (NQC * CQC)$$

Resulting in the **social** term for the Sustainable Economic Index Function:

$$EIFs = \sum_{j=1}^{n} NTj * HFP * CHFP + \sum_{j=1}^{n} NTj * HFC * CHFC + \sum_{j=1}^{n} NTj * CMEPI + (TIO * CPS) + \sum_{j=1}^{n} CIR + (NQC * CQC)$$

4.2.4. Economic Index Function (EIF)

Once the three addends relative to the production, environmental and social dimensions are determined, the Sustainable Economic Index Function value can be obtained by adding them. The total expression for this index, taking into account the importance or weight of each dimension, as α,β and γ for an organization, as referred above, is therefore:

$$EIF = \alpha\left[\sum_{j=1}^{n} Nij * TPij * CFij + \sum_{j=1}^{n} CNUj * TIj + CPIPE * TAE + \sum_{j=1}^{n} Bij * TMij * CMij + \sum_{j=1}^{n} CNUBj * TIBij\right] + \beta\left[\sum_{j=1}^{n} Mij * CMij + \sum_{j=1}^{n} Eij * CEij + \sum_{j=1}^{n} PEij * CPEz + \sum_{j=1}^{n} CAij * CCAz + \sum_{j=1}^{n} Rij * CRij + \sum_{j=1}^{n} EAij * CEAz + \sum_{j=1}^{n} ARij * CARz\right] + \gamma\left[\sum_{j=1}^{n} NTj * HFP * CHFP + \sum_{j=1}^{n} NTj * HFC * CHFC + \sum_{j=1}^{n} NTj * CMEPI + (TIO * CPS) + \sum_{j=1}^{n} CIR + (NQC * CQC)\right]$$

4.3. Integrated Assessment of Sustainable Development

The objective of Damjan Krajnc and Peter Glavic (2004) was to design a model for obtaining a composite sustainable development index (I_{CSD}) in order to track integrated information on economic, environmental, and social performance of the company with time. The main aim is to raise the quality of sustainability reporting to a higher level of consistency. Damjan Krajnc and Peter Glavic (2004) discusses how economic, environmental, and social indicators can be associated into sustainability sub-indices and finally into an overall index of a company performance. This is applied by determining the impact of individual indicator to overall sustainability of the company using the concept of analytic hierarchy process (AHP) (Saaty, 1980). The model uses normalized social, environmental, and economic indicators to incorporate them into a unique measure of performance.

Table 17 defines all variables that are used in the model proposed by Krajnc and Glavic to obtain an overall index of sustainability performance of a company:

The model reduces the number of indicators by aggregating them into a composite sustainable development index (ICSD). The model structure is based on two level aggregation of the indicators for each of the TBL dimensions, Figure 19. The ISO 31 standard is used as basis of terms, variables and symbols used, e.g. for (physical) quantities (ISO, 1993).

The procedure of calculating the ICSD index follows a number of steps as shown in Figure 20. At first, the required indicators are selected and organized in groups by the sustainability dimensions: for economic j = 1 for environmental j = 2 and for the social group of indicators j = 3. For each group indicators whose increasing value has a positive impact on sustainability are referred as IA+ and those whose increasing value has a negative impact, as IA- indicators i (see notation in

Table 18). For example, increased value of air emissions per unit of production clearly has a negative impact, while increased operating profit is a value with a positive impact to the economic performance of the company.

Table 17. Definitions of symbols and indices. (Krajnc and Glavic,2003).

Nomenclature

Symbols

I_A^+	indicator whose increasing value has positive impact in the perspective of sustainability
I_A^-	indicator whose increasing value has negative impact in the perspective of sustainability
$\overline{I}_A^+$	average value of indicator with positive impact in the period selected
$\overline{I}_A^-$	average value of indicator with negative impact in the period selected
I_{CSP}	composite sustainable development index
I_{min}^+	indicator with minimum value and positive impact on the sustainability
I_{min}^-	indicator with minimum value and negative impact on the sustainability
I_{max}^+	indicator with maximum value and positive impact on the sustainability
I_{max}^-	indicator with maximum value and negative impact on the sustainability
I_N^+	normalized indicator whose increasing value has positive impact on the sustainability
I_N^-	normalized indicator whose increasing value has negative impact on the sustainability
I_S	sustainability sub-index
r_{ECN}	rate of economic development of the company in the time interval
r_{ENV}	rate of environmental development of the company in the time interval
r_{SOC}	rate of social development of the company in the time interval
r_{SD}	rate of sustainable development of the company in the time interval
W	a priori weight of indicator

Indices

i	sustainable development indicator
j	group of sustainable development indicators

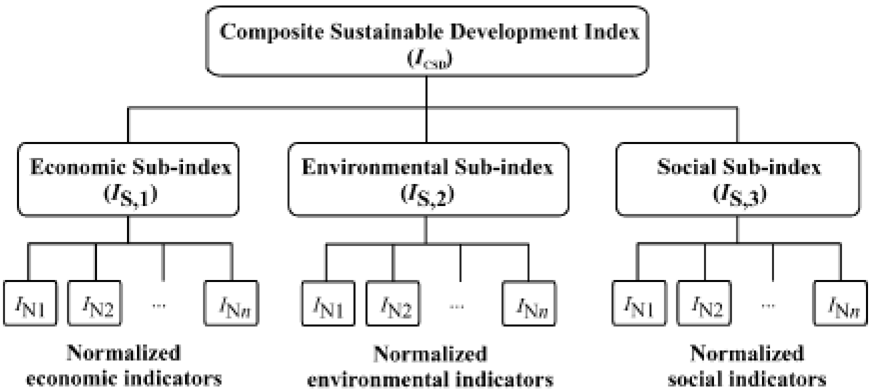


Figure 19. Generic hierarchy scheme for calculation of composite sustainable development index (Krajnc and Glavic, 2004).

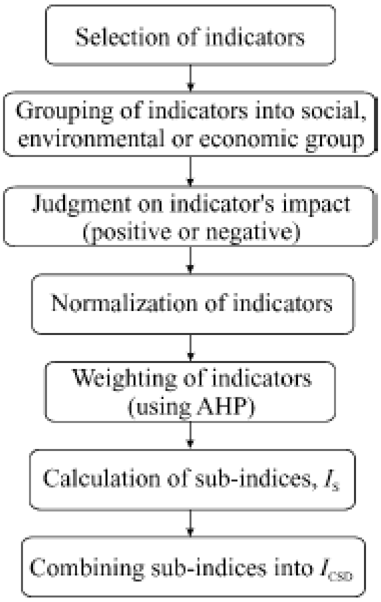


Figure 20. The procedure of calculating the ICSD (Krajnc and Glavic, 2004).

Table 18. Notation used in the definition of sustainability indicators. (Krajnc and Glavic,2003).

Group of indicators	Group notation, j	Indicators with positive impact	Indicators with negative impact
Economic group	1	$I^{+}_{A,1i}$ $i = 1, \ldots, n$	$I^{-}_{A,1i}$ $i = 1, \ldots, n$
Environmental group	2	$I^{+}_{A,2i}$ $i = 1, \ldots, n$	$I^{-}_{A,2i}$ $i = 1, \ldots, n$
Social group	3	$I^{+}_{A,3i}$ $i = 1, \ldots, n$	$I^{-}_{A,3i}$ $i = 1, \ldots, n$

The main problem of aggregating indicators into the I_{CSD} is the fact that indicators may be expressed in different units. One way to solve this problem could be normalizing each indicator by dividing its value for the period t by its average value of the time horizon under analysis (Eqs. (1) and (2)).

$$I^{+}_{N,ijt} = \frac{I^{+}_{A,ijt}}{\overline{I}^{+}_{A,ij}} \quad (1)$$

$$I^{-}_{N,ijt} = \frac{I^{-}_{A,ijt}}{\overline{I}^{-}_{A,ij}} \quad (2)$$

The second way could be normalizing each indicator i using maximum and minimum values of the time horizon under analysis, Eqs. (3) and (4).

$$I_{N,ijt}^{+} = \frac{I_{A,ijt}^{+} - I_{\min,jt}^{+}}{I_{\max,jt}^{+} - I_{\min,jt}^{+}} \quad (3)$$

$$I_{N,ijt}^{-} = 1 - \frac{I_{A,ijt}^{-} - I_{\min,jt}^{-}}{I_{\max,jt}^{-} - I_{\min,jt}^{-}} \quad (4)$$

In both ways, the possibility of incorporating different kinds of quantities, with different units of measurement (i.e. physical, economic, etc.), is offered. Among the advantages of the proposed normalization of indicators is the clear compatibility of different indicators, since all indicators are normalized.

However, it is not necessary that the indicators are normalized as mentioned above. The companies can set specific targets for each indicator according to their goals and capabilities towards SD.

The next procedural part of calculating the I_{CSD} involves determining weights, which should be combined with each indicator. However, to determine weights of environmental indicators the evaluator is often confronted with a lack of data. Even more difficulties can be expected in obtaining the weights for social and economic indicators. Therefore, to derive the weights practically, the analytic hierarchy process (AHP) was used in the model. So the AHP is required to determine relative weights of indicators in the overall index of sustainability.

The AHP (Saaty, 1980) has been accepted as a leading multi-attribute decision model, both by practitioners and academics. In this dissertation it is tested to derive weights of indicators by the prioritization of their impact to overall sustainability assessment of the company (see Figure 19).

The first step sets the problem as a hierarchy, where the topmost node is the overall objective of the decision, while subsequent nodes at lower levels consist of the criteria used in arriving at this decision.

The second step requires pair-wise comparisons to be made between each pair of indicators (of the same level of the hierarchy). The comparisons are made by posing the question which of the two indicators i and j is more important with respect to the sustainability of the company.

The intensity of preference is expressed on a factor scale from 1 to 9 Table 19. The value of 1 indicates equality between the two indicators while a preference of 9 indicates that one indicator is nine times the importance of the one to which it is being compared, and consequently this is nine times less important.

Table 19. Comparison scale of analytic hierarchy process [Hafeez et al., 2002]

Factor of preference, *p*	Importance definition
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance of one over another
7	Very strong or demonstrated importance of one over another
9	Extreme importance of one over another
2, 4, 6, 8	Intermediate values
Reciprocal, 1/*p*	Reciprocal for inverse comparison

These pair-wise comparisons result in a ($N \times N$) positive reciprocal matrix *A*, where the diagonal a_{ii} = 1 and reciprocal property $a_{ji} = (1/a_{ij})$, $i, j = 1, \ldots, n$ assuming: if indicator *i* is "*p* times" the importance of indicator *j*, then, necessarily, indicator *j* is "1/*p*-times" the importance of indicator *i*.

First, only the first row of the impact prioritization matrix *A* is provided, i.e., the relative importance of indicators 2, 3, . . ., *n*, with respect to indicator 1. Then the process of comparison is repeated for each row of the matrix, making independent judgments over each pair of indicators. At the end of the comparisons, the matrix *A* is filled with the relative weights, as you can see in Table 20 .

Table 20. Matrix A, with p= factor of preference

	indicator 1	indicator 2	indicator 3	indicator 4	indicator n
indicator 1	1	p	p	p	p
indicator 2	1/p	1	…	…	…
indicator 3	1/p	…	1	…	…
indicator 4	1/p	…	…	1	…
indicator n	1/p	…	…	…	1

A quick way to find the normalized weight of each indicator is normalizing each column in matrix *A* (dividing an indicator relative weight by the sum of relative weights in column), and then averaging the values across the rows; this average column is the normalized weight vector ***W*** containing weights (W_{ji}) of sustainability indicators selected.

The AHP also provides a measure called the consistency ratio (Rc) to check the consistency of each judgment. Inconsistency is likely to occur when decision-maker makes careless errors or exaggerated judgments during the process of pair-wise comparison. A consistency ratio of 0.1 is considered as the acceptable upper limit. If the consistency ratio is greater than 0.1 then the decision-maker has to re-evaluate his judgments in pair-wise comparison matrix until the ratio is finally less than 0.1.

The calculation of the I_{CSD} is a step-by-step procedure of grouping various basic indicators into the sustainability sub-indices ($I_{S,j}$) for each group j of sustainability indicators. Sub-indices can be derived as shown in Eq. (5).

$$I_{S,jt} = \sum_{jit}^{n} W_{ji} \cdot I^{+}_{N,jit} + \sum_{jit}^{n} W_{ji} \cdot I^{-}_{N,jit} \qquad (5)$$

$$\sum_{ji}^{n} W_{ji} = 1, \quad W_{ji} \geq 0$$

Where

$I_{S,jt}$ is the sustainability sub-index for a group j of n indicator, with j = 1, 2 or 3 in time (year) t.

W_{ji} is the weight of indicator i for the group of sustainability indicators j and reflects the importance of this indicator in the sustainability assessment of the company.

Finally, the sustainability sub-indices are combined into the composite sustainable *development* index I_{CSD} (Eq. (6)).

$$I_{CSD,t} = \sum_{jt}^{n} W_j \cdot I_{S,jt} \qquad (6)$$

Where W_j denotes the factor representing a priori weight given to the group j of indicators. These weights should reflect hierarchies and/or priorities in the opinion of the decision makers. In the final calculation of the I_{CSD}, an approach that estimates these weights can be considered. These weights reflect the importance given to the economic, environmental, and social performance of the company.

5. A contribution for measuring and improving manufacturing sustainability of companies

5.1. Critical vision of chapters 3 and 4

Chapter three introduces the concept of indicators referring that if they are used to evaluate sustainability of organizations they may be called sustainability's indicators. A list of these, organized in classes, e.g. based on the TBL dimensions, is given. Moreover, it also put forward frameworks that have been proposed and developed to measure, evaluate and report sustainability, based on sustainable indicators.

Chapter four extends chapter three defining and presenting composite indicators, suggesting its usefulness for decision-making and as guiding instruments to better integration of decision-making in a company. It also refers the complexity of developing composite indicators and the need to normalise them towards the definition of indices that aggregate in a sensible manner indicators of different nature and units of measurement. However, the chapter does not develop enough the normalising problematic, neither answer important questions for a company to become a sustainable company. In fact, when some company needs to evaluate its sustainability stand or become a sustainable company, typical doubts and questions arise, namely:

- Which kind of indicators should and can we measure?
- What framework for sustainability guidance and measurement should we adopt?
- How to develop an index that should and can be used for sustainability measurement an guidance.

Existence of many indicator sets has created confusion among manufacturers when they attempt to select an operational set of indicators for assessing sustainability in manufacturing. Specifically, manufacturing enterprises have been challenged to decide which indicators to choose to evaluate their processes and products, and how they should interpret these indicators in making their processes and products sustainable. Sikdar (2003) stated that no consensus existed on a reasonable taxonomy of sustainability-related metrics. Similarly, Gaurav et al., (2008) state in a literature review that major sustainability metrics are inconsistently defined and business-specific.

In this dissertation we collected a list of sustainable indicators, most of them organized in three main groups according to what has been referred as the TBL three dimensions. But multi-dimensional sustainability is difficult to assert because several aspects of each dimension are interrelated, i.e., they are not independent.

As referred the list of the LCSP, for sustainable production indicators, addressing six aspects namely energy and material use (resources), natural environment (sinks), social justice and community development, economic performance, workers, and products is quite extensive and include 22 core indicators and many more others, organized in a five-level indicator framework. The framework is based on nine guiding principles to which are the indicators associated with.

An even more extensive list, organized in five dimensions, namely environmental stewardship, economic growth, social well-being, technological advancement, and performance management, was prepared by NIST's (Japan National Institute of Science and Technology Policy).It contains 212 sustainable indicators originated from several sources including e.g., the NIST itself, CRI and ISO 14031). Further detail of this structure and the indicators within this structure can be found at the NIST's complete repository (SMIR) website (http://www.mel.nist.gov/msid/SMIR/Indicator_Repository.html).

Chapter three also analyses the importance of frameworks and their use as guidelines for understanding the suitability of each framework to measure sustainable manufacturing. Here we focussed particular attention to the LCSP, GRI and ISO 14031 frameworks.

Today one of the frameworks more referred in the literature on sustainable manufacturing is the GRI. It is based on collecting and process information about GRI´s data partners reporting and sustainability reporting in general. They regularly share data with GRI about reports and reporting organizations, and also serve as on-the-ground hubs, identifying reporting trends in their countries and regions (web site [7]). The report and organization related information provided by Data Partners is added to GRI's Sustainability Disclosure Database. The GRI Guidelines call for disclosures that should facilitate comparisons between companies and between time periods within companies. This can greatly enhance users' understanding of past performance and likely future prospects; beyond what Management's Discussion and Analysis disclosures and other parts of annual reports typically provide (Willis, 2003). The network is supported by an institutional side of the GRI, which is made up of the following governance bodies: Board of Directors, Stakeholder Council, Technical Advisory Committee, Organizational Stakeholders, and a Secretariat. Diverse geographic and sector constituencies are represented in these governance bodies. The GRI headquarters and Secretariat is in Amsterdam, Netherlands.

However, a common criticism of GRI and the GRI guidelines is that the focus is on more reporting, not better reporting or more usable or actionable reporting. GRI's focus has been to continually get governments and stock exchanges to require more organisations around the world to produce sustainability reports, preferably with using the GRI guidelines. The focus on quantity over quality supports the value of GRI's brand but has also resulted in many reports that are little more than public relations efforts. Furthermore, data quality and audit and assurance of non-financial accounting practices are not a primary focus of GRI. Non-financial audit or assurance is not a required part of reporting in accordance with the GRI guidelines. In addition, while GRI prides itself on its multi-stakeholder approach, investors were not invited to participate in the creation of the guidelines until recently. While GRI pushes for more reporting, they have done little to increase or even assess the impact of existing sustainability reports. While sustainability reporting is intended to make economic development sustainable in light of planetary limits, in practice, most organisations report performance against their own historical performance, against short-term targets developed internally or against industry best practice. GRI's Sustainability Context Principle "involves discussing the performance of the organisation in the context of limits and demands placed on environmental or social resources at the sector, local, regional, or global level." However, GRI provides little guidance on how to do this, and most organisations that use the GRI guidelines for sustainability reporting do not report performance in this context (web site [8]).

Finally, chapter 4 explains the importance of the sustainability index. Interpretability with indicator sets is a key issue because the complexity of the interrelationships of indicators causes a number of contrary conclusions about the level of sustainability and what can be done to improve it (Kibira et al., 2009; Ueda et al., 2009). In contrast to indicator sets, indices provide a more straightforward conclusion on the level of sustainability because they rely on weight-based mathematical methods to aggregate many indicators into a single score. This chapter explains two indices, and the methods for achieving the score. The first index analysed is Economic and Functional Efficiency Index, or Economical Index function (EIF) of a sustainable production line (Ares et al. 2012).This index is based on three fundamental aspects of sustainable production – Productive, Social and Environment - and it has one sub-index for each aspect weighted adding by coefficients α, β and γ dependent on the strategy or characteristics of the company and on the importance of each operation or machine of the company. It should be remarked that this is an index which is focused on production lines of a manufacturing company and, therefore, not an appropriate for other type of companies e.g., service companies. The EIF solve the normalizing problem by dealing only with cost variables or indicators, but no explanation is given on how the weight of each of the three dimensions evaluated can be obtained. Moreover the function deals with variables that are not clear namely the n index used in the summation and the CPIPE used in the model.

The second index is an Integrated Assessment of Sustainable Development developed by Damjan Krajnc and Peter Glavic. This index uses normalized social, environmental, and economic indicators to incorporate them into a unique measure of performance. Contrarily to the EIF index, this can be applied for any type of company. The method is based on subjective judgment mainly because it is based on a subjective process of pair-wise comparisons of importance of indicators for sustainability, based on a Likert scale. The use of a consistency ratio (Rc) ensures that notorious errors on the subjective judgments are avoided. Since the method to obtain the index can use indicators of different nature, i.e. measured in different units, the method uses AHP for normalizing procedures in order to arrive to the Krajnc and Glavic index composed of sub-indices for each of the sustainable dimensions considered,, e.g. those of the TBL.

5.2. A proposed approach to evaluate production/company sustainability

Previous chapters and almost the entire of this dissertation is based on a bibliography research and focused on many things related with sustainable development and production.

In this chapter a proposed approach to evaluate production sustainability is attempted. It is based on an index, flexibly composed according to company needs, vision and strategies on production sustainability and available data. Actually it can be narrow focussed or be based on an indicator set as large as wished and possible.

This approach has the following basis steps:

1. Establish and select measurable simple indicators that matter for sustainability:
   Each company is different and thus, each company has different needs that must be measurable. Therefore, in this first step each company must choose the number and type of simple indicators that it want to use for measuring sustainability. It is important identify and separate them into two groups' indicators: those whose increasing value has a positive impact on sustainability and those which have negative impact.
2. Establish target values that must be achieved and achievable for each of the indicators selected to meet the required minimum sustainability. Essentially this defines the sustainability threshold value of each indicator used. These thresholds could be based on target values established according to environmental regulations, restrictions or simply targets that the company proposes to achieve as a challenge to improve its sustainability stand.
3. Since the importance of sustainability indicators is typically different from each other in a company and probably different from company to company, it is necessary to establish weights for each indicator according to its relative importance for each company. In this step, there are two ways for establishing weights for each indicator. The first one is establishing weights through the decision-makers criteria. Thus, indicator is affected by weighting factor. This should reflect company's strategy towards sustainable production and be dependent on company's characteristics. The Second option is using analytic hierarchy process (AHP) to derive the weights (W_i) practically. Actually, in this process management judgement about the relative importance of each indicator is also necessary. Chapter 4.3 explains AHP technique for this purpose.

4. Establish the relative overall score of sustainability in relation to targets, having the weights into account: this could be achieved normalizing each indicator by dividing its value in time with its average value at the same time in years measured, or another way by dividing its value with its minimum sustainability target .

$$\mathrm{In} = \frac{\mathrm{Imeasured}}{\mathrm{Itarget\ or\ averaged}}$$

   Where:

   - I_n: normalized indicator, which could be with positive impact or with negative impact on SD.
   - I_n^+ normalized indicator, which has a positive impact or with negative impact on SD

- I_n^- normalized indicator, which has a negative impact or with negative impact on SD
- $I_{measured}$: it is the measured value.
- $I_{target, averaged}$: it is the target or averaged measure for the time horizon under analysis used for normalizing the sustainability indicator.

5. Measure the value of the indicators in the organization and the calculation of the sustainability index of the company I_{SD}.

$$\sum_{i=1}^{n} W_i * I_{n,i}^{+} + \sum_{i=1}^{n} W_i * I_{n,i}^{-}$$

The proposed index is similar to Krajnc and Glavic index but easier to develop and apply , enabling to define sustainability simply based on a set of chosen indicators independently of clustering them in dimensions of sustainability. This way we avoid to use indicators that may not be fully independent from each other and leave to the company the decision or the choice of the sustainability indicators that matter for the company. In this respect emphasis can be put on sustainable production indicators if sustainable production needs to be measured. Moreover different perspectives of sustainability can be accommodated. So in a single pass we get the value of the index, contrarily to the need of two passes due to a hierarchy of indicators and indices required to get to the index devised by Krajnc and Glavic. The same principle of expert judgment about the importance of an indicator for sustainability, adopted by Krajnc and Glavic is also used in our method.

5.3. Example analysis of sustainability of a company

To better explain this method, a case example will be conducted. The company selected is Grupo Bimbo. Grupo Bimbo is a global banking leader with more than 127 mil associates, operating in 19 countries with a broad asset base. The company was founded in 1947 with only a plant and 10 delivery trucks in Mexico DF. Today this group includes 156 plants, more than 50,000 distribution routes, and over 2 million points of sale. Its portfolio has more than 8,000 products and 103 highly prestigious umbrella brands in the baked goods, salted snacks, confectionery, wheat tortillas and packaged food categories, among others.

Grupo Bimbo is really committed with responsible social and environmental performance. “The main objective of the Grupo Bimbo is to standardize criteria for action at every level and position throughout the world, to grow steadily using sustainable resources”, this is one of the mottos of the group. To report its CSR and environmental performance, Grupo Bimbo is integrated in GRI (Global Reporting Initiative). According to the methodology defined by the GRI, its principles, parameters, and indicator protocols, in 2011 they prepared the report based on the directives of the GRI G3.1 Guidelines (the data base that we will select for our case study will fixed on years 2009, 2010 and 2011), and earned a GRI application grade of B. In this report, they included indicators on economic results, responsible procurement, labour practices and environment, which they integrated into each pillar of their “Commitments”.

We selected some of them, distributed among economic indicators, social indicators, and environmental indicators, and they are:

- **Total emissions of CO_2 (in tons of CO_2) (ECO_2):** This metric is the generation of equivalent carbon dioxide (CO2e) emissions by energy source. These data corresponds to the organizations described in the "Coverage" column of Indicator EN 16, in the GRI Content table. To calculate CO2e emissions from the use of fossil fuels, they used emission factors from the guide prepared by the Greenhouse Gas Protocol Initiative (GHG Protocol) and the Mexican Greenhouse Gas Protocol (GHG Mexico). Increasing this measure will have negative impact on the I_{sd}.
- **Water consumption (in m^3)(W):** They introduced a resource balancing methodology to continued protecting and reducing water consumption. They recorded more than 60 actions, most of which are good practices to avoid water waste: pressurized water, dry and semi-dry cleaning, development of cleaning kits etc. These data correspond to the organizations described in the "Coverage" column of indicator EN8, in the GRI Content table. Increasing this measure will have negative impact on the I_{sd}.
- **Consumption of Kwh of electricity per metric ton (KWH):** The data correspond to the organizations described in the "Coverage" column of indicator EN5 and EN18, in the GRI Content. Increasing this measure will have negative impact on the I_{sd}.
- **Consumption of Gcal of Natural Gas by metric ton (GCAL):** The data correspond to the organizations described in the "Coverage" column of indicator EN5 and EN18, in the GRI Content. Increasing this measure will have negative impact on the I_{sd}.
- **Number of workers (payroll, contract and independent)(NW):** This metric includes information on the total associates of Grupo Bimbo, S.A.B. de C.V. as of December 2011, including the new companies acquired in 2011. It is the only indicator with this coverage in our 2011 Sustainability Report. Increasing this measure will have positive impact on the I_{sd}.
- **Incident Rate (IR):** it is the total number of accidents divided into total hours worked, for every 200,000 working hours. This rate reflects the incidence of both fatal and nonfatal accidents that occurred on the job or as a result of it. This data correspond to the organizations described in the "Coverage" column of indicator LA7 found in the GRI Content table. Increasing this measure will have negative impact on the I_{sd}.
- **Lost Days Rate (LDR):** total number of workdays lost in proportion to total hours works for every 200,000 working hours. This rate reflects the amount of time not worked (hence, "lost days") because the worker or workers could not do their usual job as a result of a professional or workplace accident or illness. This data correspond to the organizations described in the "Coverage" column of indicator LA7 found in the GRI Content table. Increasing this measure will have negative impact on the I_{sd}.
- **Investment in training (IT):** Total training hours” in 2011 include: technical training, induction and additional education (including human rights courses such as CUSUPE). In earlier years, it was included only conventional training. Data correspond to the organizations described in the “Coverage” column of indicator LA10 found in the GRI Content table. Increasing this measure will have positive impact on the I_{sd}.

- **Net Sales (in millions of nominal pesos)(NS):** Consolidated results exclude inter-company transactions. Increasing this measure will have positive impact on the I_{sd}.

The data base of each indicator is shown below in Table 21:

Table 21. Data base of each indicator.

	2009	2010	2011	I_{target}
ECO_2	1342624	1237646	1260624	1350000
WT	3870000	3660000	3720000	3900000
KWH	215.02	211.06	210.88	215
GCAL	0.5889	0.5221	0.5243	0.6
NW	118321	114540	133602	115000
IR	2.15%	2.22%	2.32%	2.15
LDR	80%	60%	163%	100
IT	87298000	115006000	208093013	80000000
NS	1.1635E+11	1.1716E+11	1.3371E+11	1.15E+11

Then, weights of each indicator are calculated following the AHP method, and the results are shown in Table 22.

The value 0,5 in cell (ECO2,NS) means that the Ns indicator is 0,5 times more important than ECO_2 for the sustainability of the company. The same is to say that ECO_2 is twice as important as NS.

Table 22. Weights of each indicator using AHP and Matrix A.

	ECO_2	W	KWH	GCAL	NW	IR	LDR	IT	NS	weights
ECO_2	1	1	1	1	3	3	3	3	0.5	
WT	1	1	1	1	3	3	3	3	0.5	
KWH	1	1	1	1	3	3	3	3	0.5	
GCAL	1	1	1	1	3	3	3	3	0.5	
NW	0.33	0.33	0.33	0.33	1	1	1	1	0.33	
IR	0.33	0.33	0.33	0.33	1	1	1	1	0.33	
LDR	0.33	0.33	0.33	0.33	1	1	1	1	0.33	
IT	0.33	0.33	0.33	0.33	1	1	1	1	0.33	
NS	2	2	2	2	3	3	3	3	1	
Σ	7.33	7.33	7.33	7.33	19.00	19.00	19.00	19.00	4.33	
ECO_2	0.13636364	0.13636364	0.136363636	0.13636364	0.15789474	0.15789474	0.15789474	0.15789474	0.11538462	0.143602012
WT	0.13636364	0.13636364	0.136363636	0.13636364	0.15789474	0.15789474	0.15789474	0.15789474	0.11538462	0.143602012
KWH	0.13636364	0.13636364	0.136363636	0.13636364	0.15789474	0.15789474	0.15789474	0.15789474	0.11538462	0.143602012
GCAL	0.13636364	0.13636364	0.136363636	0.13636364	0.15789474	0.15789474	0.15789474	0.15789474	0.11538462	0.143602012
NW	0.04545455	0.04545455	0.045454545	0.04545455	0.05263158	0.05263158	0.05263158	0.05263158	0.07692308	0.052140842
IR	0.04545455	0.04545455	0.045454545	0.04545455	0.05263158	0.05263158	0.05263158	0.05263158	0.07692308	0.052140842
LDR	0.04545455	0.04545455	0.045454545	0.04545455	0.05263158	0.05263158	0.05263158	0.05263158	0.07692308	0.052140842
IT	0.04545455	0.04545455	0.045454545	0.04545455	0.05263158	0.05263158	0.05263158	0.05263158	0.07692308	0.052140842
NS	0.27272727	0.27272727	0.272727273	0.27272727	0.15789474	0.15789474	0.15789474	0.15789474	0.23076923	0.217028585

Normalized data base of each indicator (calculated by dividing each indicator by its I_{target}) in the next next

Table 23:

Table 23. Normalized indicators.

I_N	2009	2010	2011
ECO_2	0.9945363	0.91677481	0.93379556
WT	0.99230769	0.93846154	0.95384615
KWH	1.00009302	0.98167442	0.98083721
GCAL	0.9815	0.87016667	0.87383333
NW	1.02887826	0.996	1.16175652
IR	0.01	0.01032558	0.0107907
LDR	0.008	0.006	0.0163
IT	1.091225	1.437575	2.60116266
NS	1.01176522	1.0188087	1.16271304

Each normalized indicator multiplied by its weight in Table 24:

Table 24. Normalized indicator multiplied by its weight

$W*I_N$	2009	2010	2011
$W*ECO_2$	0.14281741	0.13165071	0.13409492
W*WT	0.14249738	0.13476497	0.13697423
W*KWH	0.14361537	0.14097042	0.1408502
W*GCAL	0.14094537	0.12495768	0.12548422
W*NW	0.05364658	0.05193228	0.06057496
W*IR	0.00052141	0.00053838	0.00056264
W*LDR	0.00041713	0.00031285	0.0008499
W*IT	0.05689739	0.07495637	0.13562681
W*NS	0.21958197	0.22111061	0.25234197

And finally the I_{sd} index, below, applying the equation of the point 5º of the method, in Table 25:

Table 25. I_{sd} index results.

	2009	2010	2011
I_{sd}	-0.35448291	-0.33510849	-0.36152598

At first we can see that I_{sd} was negative for the three years. The simply reason is because indicators that we select are most indicators with negative impact, only number of workers, net sales and investment in training has positive impact on the I_{sd}. Second point is the trend of the I_{sd}. The result shows a positive trend in the range of 2009 and 2010, but follows a negative trend in the next range of 2010 and 2011. This does not mean necessarily that this company is on the wrong way to sustainable development. It only means that this index with indicators selected is having a negative trend at the end of the 2011. If the company selects more indicators we could see more reliable the overall result of the company.

6. Conclusions and future work

Sustainable development is becoming increasingly important for industry. This dissertation focuses on company and production sustainability and gives an averall view of frameworks and indicators of sustainable production and developement. This dissertation addresses and attempts to answer the following research questions: How can a company become a sustainable company? How can sustainability evolution be measured? How and which sustainability metrics and targets can be used and set? What new coontribution can be given to measure a company and production sustainability.

In relation to the first question no clear answers were found in the literature reviewed. One approach that emerged is that it must be based on norms and regulations and company strategic objectives on economic social and environmental aspects. However this must be evaluated. To do this, a list of several indicators is given in this dissertation, collected from reviewing of several frameworks on company sustainability.

Evolution of sustainability is evaluated based on data from a horizon period of analysis and on the values measured for the different indicators. One serious difficulty with evaluation of sustainability is the normalization of the values measured for indicators of very different nature. It came out from this study that the Analytical Hierarchy Process (AHP) is a technique quite useful for normalization of measures, not only based on targets aligned with sustainability strategies and tactics of a company, but also to simple evaluation of evolution of the indicators to assess sustainability.

The approaches to measure sustainability usually aggregate indicators into indices, or composite indicators, according to the TBL dimensions, i.e. economic, social and environmental, giving different weights to each indicator and dimension, and then a further aggregation of these indices into a single index of sustainability is performed. This two level aggregation tend to hide the true meaning of the indices and the index, and make it difficult to evaluate sustainability. Moreover, due to somewhat subjective classification of some indicators as belonging to social, economic or environmental groups, the indices for each of these dimensions cannot be seen as truly independent.

In this dissertation we present a flexible index of company and production sustainability , based on a single level of aggregation, i.e., without aggregation based on the TBL dimensions or any others, of relevant and recommended individual indicators of sustainability. This simplifies the index and its interpretation, allowing a company to adapt the index to its strategies of sustainability by selecting only the indicators judged relevant for sustainability and sustainability evolution analysis. The indicators used in this index are normalized with basis on the AHP technique. One particular advantage of our index is its versatility and simple adaptation and application to a wide range of organizations and the easy normalization of measures based on the AHP technique.

Our proposed index for measuring sustainability emerged after the review of some frameworks for sustainable development and the analysis of simple and composite indicators to measure aspects and dimensions of sustainability. In relation to frameworks we particularly emphasize the GRI framework, probably the most widely used and recommended for sustainability evaluation and reporting (GRI, 2006). From studies on indicators and composite indicators that contributed to the index proposed in this dissertation, we emphasize those developed by Ares et al (2012), the so called Economic Index Function (EIF) of a sustainable production, and mainly the composite indicators for "Integrated Assessment of Sustainable Development", developed by Krajnc and Glavic (2003).

We recognize that the field of research addressed in this dissertation is very vast and that a lot of research is still required to arrive to sustainability norms and indices of simple interpretation but valuable meaning that make possible and easier company and production sustainability measurement for sustainability evolution analysis and also for comparisons across companies, within each industrial sector, and across industrial sectors. This will surely make it easier to establish sustainability targets and facilitate the definition and implementation of business strategies complying with sustainability requirements.

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