Sustainable Design Series of
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LCA-based assessment of sustainability: the Eco-costs/ Value Ratio

EVR

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Original publications on the theory, updated with eco-costs 2007 data

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Preface and Acknowledgements

The ever growing economy seems to be one of the major root-causes of the continuing deterioration of our environment. The question is: what can be done? Stopping the economic growth seems no realistic option, so the solution must be found in a better eco-efficiency of our systems for production and consumption ("de-linking of economy and ecology").
Future products and services need to have a high value/costs ratio combined with a low burden for our environment. This is the challenge for modern designers, engineers, business management and governmental leaders.

This book is on the basic aspects of the Model of the Ecocosts/Value Ratio, an LCA based Decision Support Tool on the sustainability of products and services. It is a compilation of the original publications in scientific journals (peer reviewed), and some additional issues of the Doctorate Thesis which were not published in journals.

After the first set of publications on the eco-costs in the period 1999–2004, the system of the eco-costs has been renewed, resulting in a new dataset: the eco-costs 2007, based on new characterization tables for more then 3000 emissions, and based on a new curve of the marginal prevention costs of summer smog ('photochemical oxidation' or 'respiratory organics') and a new assessment of carciogens. The marginal prevention costs of the other 'midpoints' were checked and corrected for monetary inflation of costs.
For the convenience of the reader, the tables and the numbers in the text have been updated accordingly.

Acknowledgements

There are so many people who contributed to the model, that it is not feasible to name them all. Some people, however, did more than only comment the ideas, but contributed to specific issues of the model: Bianca Baetens (recycling of construction materials for buildings), Arianne Bijma (the issue of communication), Eduard Brandjes (the transport case), Dolf Gielen (eco-costs of energy), Erwin Lindeijer (land-use), Merel Segers (eco-costs 2007 calculations) and Flip Witte (botanical value and eco-costs of land).
I would like to express my gratitude for the valuable contribution of prof.dr.ir. J.C. Brezet and prof.dr.ir. Ch.F. Hendriks †. Without their contribution, the development of the EVR model would not have succeeded.

Delft University of Technology, the Netherlands, November 2009
Joost G. Vogtländer

Preamble

Prosperity: a fragile balance between economy and nature

On Venice, 1974:

" . . . . . Almost every winter for many years, large parts of the city have become flooded. Indeed, this is becoming an even more frequent occurrence. It is due to the subsidence of the entire area under and around the lagoon, which in turn has been caused by the abstraction of groundwater by industry and agriculture in the surrounding region. … The rising local seawater level has caused damp in the walls of many buildings, which has damaged many paintings and frescos. Air pollution, caused by a chemical industry which is not adequately supervised, has caused irreparable damage to sculptures and buildings. Much has already been lost and unless action is taken soon, at least half of the art treasures which remain will also be lost within the next forty years. … The problems faced by Venice are primarily of a social nature. Tourism does not provide sufficient revenue for the winter months. Young people prefer to live on the mainland, where they can have their own car parked outside the front door rather than having to walk or rely on boats. Houses in Venice itself are rapidly decaying. New sources of revenue must therefore be found in order to make the old city an attractive place to live in once more … "

From: *Grote Winkler Prins Encyclopaedia*, seventh edition, 1974, (in translation).

It is with some hesitation that I selected the above to serve as the introduction to this book. Is it relevant to the topic of sustainability and eco-efficiency? Is the picture presented a realistic one? Can the same phenomenon, or one broadly similar, also be seen elsewhere?
The situation described presents many facets of the same reality. However, the significant characteristic is that it is impoverishment which is leading to decay: there are insufficient funds for maintenance, let alone for new measures such as the construction of a drainage system. Faced with the threat of greater unemployment, the government allows industry and agriculture to place an unwarranted burden on the local environment. (This is a dilemma we have seen not only in Eastern European countries and the developing countries, but also in the Netherlands. Here too, numerous instances can be cited in which the government has succumbed to pressure from various business lobby groups and has failed to take appropriate measures, resulting in harm to the environment).

For Venice, the prospects are now more encouraging than was the case twenty years ago:

- the Italian government has now prohibited any further abstraction of water by industry
- the historic city centre is being refurbished with international assistance

- new economic activity is being developed in the service sector, located in the city centre.

The new challenge, however, is to withstand the ever growing mass of tourists who are attracted by inexpensive travel arrangements, and to withstand the increased frequency of flooding.

The policy to be adopted is clear: the city can only survive if it has sufficient economic strength (i.e. ongoing prosperity) to be able to stop the ecologically harmful activities, construct sewers, and perhaps construct a seawater barrier which is normally open but can be closed at high tides.
At the same time, strong economic growth must not itself result in any additional environmental impact (e.g. de-linking of economy and ecology is the key to a sustainable development)

It would seem that in our modern world, the concept of 'sustainability' has become quite complex. It now goes far beyond the encouragement of an alternative 'simpler' lifestyle (Dutch: 'consuminderen'), as is illustrated by the anecdote on Diogenes:
when Alexander the Great promised him anything whatsoever he might desire, Diogenes merely asked Alexander to stand aside, out of the sun.

Palazzo Capello Malipiero, La Volta del Canal, Venice: 'Water is a boon in the desert, but the drowning man curses it' (English proverb).

Contents

1 Introduction

1.1 Purpose of this book

The primary purpose of this book is to provide students, and other people who are interested in the subject of sustainablility, with theoretical background information on the eco-costs system and the model of the Eco-costs/Value Ratio (EVR).[1]

Eco-costs is a measure to express the amount of environmental burden of a product on the basis of prevention of that burden. It are the costs which should be made to reduce the environmental pollution and materials depletion in our world to a level which is in line with the carrying capacity of our earth.
For example: for each 1000 kg CO_2 emission, one should invest € 135.– in offshore windmill parks (and other CO_2 reduction systems at that price or less). When this is done consequently, the total CO_2 emissions in the world will be reduced by 65% compared to the emissions in 2008. As a result global warming will stabilize. In short: "the eco-costs of 1000 kg CO_2 are € 135.–".
Similar calculations can be made on the environmental burden of acidification, eutrification, summer smog, fine dust, eco-toxicity, and the use of metals, fossil fuels and land (nature). As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains. The eco-costs should be regarded as hidden obligations.
The eco-costs of a product are the sum of all eco-costs of emissions and use of materials and energy during the life cycle "from cradle to cradle". Eco-costs calculations are based on Life Cycle Assessment (LCA), as defined in ISO 14040 and 14044.
The practical use of eco-costs is to compare the sustainability of several product types with the same functionality. The advantage of eco-costs is that they are expressed in a standardized monetary value (€) which appears to be easily understood 'by instinct'. The calculation is transparent and relatively easy, compared to damage based models.

The EVR is a so-called E/E indicator ("Ecology/Economy Indicator") which can be applied in cases where a designer (architect, product engineer, marketing manager, etc.) is asked to design a product (a house, a road, an appliance, a service, etc.) within a given

[1] For specialists it is often not easy to understand the eco-costs system and the model of the EVR. The main reason for this is that it requires a fundamental paradigm shift to make the step from 'damage based' systems (which are common in LCA) to 'prevention based' systems. On paradigm shifts, Edward de Bono said: "you cannot see what your mind is not prepared for".

price (budget). The issue then is to create maximum value for the end-user at a minimum of eco-costs (environmental burden). We call this 'ecoefficient value creation'.
The EVR model can not only be applied in the stage where the design is ready (the classic LCA approach), but can also be applied in the early design stages of feasibility studies (when data on costs and market values are estimated). Calculations in combination with LCC and WLC are possible as well.

The rather complex issue of 'allocation' in Product-Service Systems and in the End of Life phase, has been resolved in a practical and consistent way (where the existing LCA methodology failed until now to provide sufficient practical answers). This makes the system suitable for Cradle to Cradle calculations.
Furthermore the model comprises a system for modelling the issue of land-use, to be able to facilitate decisions with regard to spatial planning.
The theoretical basis of the model has been introduced in 1999, and published in 2000-2004 in the International Journal of LCA (Vogtländer, Bijma, 2000, Vogtländer, Brezet, Hendiks, 2001,B, Vogtländer, Hendriks, Brezet, 2001,C)and also in the Journal of Cleaner Production (Vogtländer, Bijma, Brezet, 2002, Vogtländer, Lindeijer, Witte, Hendiks, 2004). This book is a compilation of these publications and some important additional issues from the Doctorate Thesis on the EVR (Vogtländer, 2001,A).
For the convenience of the reader, the tables and the numbers in the text have been updated according to the new set of data, the eco-costs 2007, so that information in the publication has become in line with data which are provided in the other books of the Sustainable Design Series of the Delft University of Technology and the website www.ecocostsvalue.com.

1.2 Mission

In November 1993, the World Council for Sustainable Development (WBCSD) defined eco-efficiency as:

> "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."

This business oriented definition links two aspects of good governance:

- Modern management practice ("*the delivery of competitively priced goods and services … quality of life")*.
- The need of a sustainable society *("while progressively reducing … to … earth's carrying capacity"*).

The first part of the sentence asks for a maximum value/costs ratio of the business

chain, the second part of the sentence requires that this is achieved at a minimum level of ecological impact. But what does this rather philosophical definition mean to business managers, designers and engineers in terms of the practical decisions they take?

There is a need to resolve simple questions like: what is the best product design in terms of ecological impact?, what is the best product portfolio in terms of sustainability?, what is the best sustainable strategy?

These issues are also related to the Triple P concept of the triple 'bottom line' as formulated by John Elkington (Elkington, 1998). In corporate decision taking, equal weight should be given to the following three aspects:

- 'People', the social consequences of the total Life Cycle
- 'Planet', the ecological consequences
- 'Profit', the economic profitability (being the source of 'Prosperity')

The EVR model unravels the system of the 3 P's, primarily analysing carefully the P of Prosperity (value) and the P of Planet (eco-costs), and analysing the interaction of these 2 P's in the total system. See Figure 1.1.

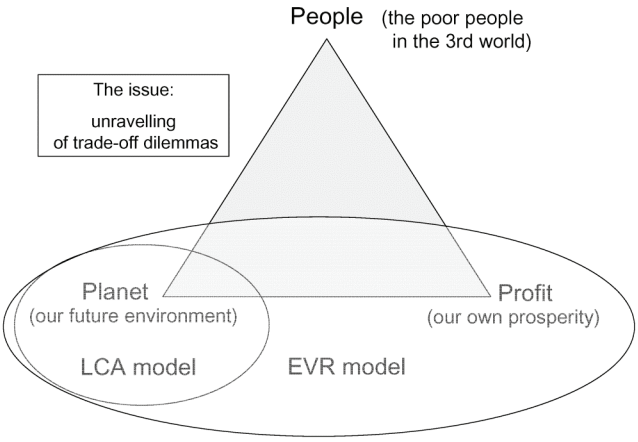

Figure 1.1. The EVR model is about 2 P's of the triple P model.

The third P, the P of People (of the developing world) is of an extreme complex nature, but related to eco-efficiency as well. The need for a better organized economy, de-linking the economic growth and the environmental degradation, was expressed for the first time in the Brundtland Report 'Our Common Future' (1987, page xii, see also Appendix 1), as the conclusion of a study on the situation in the developing countries:

> "The downward spiral of poverty and environmental degradation is waste of opportunities and of resources. In particular it is a waste of human resources. These links between poverty, inequality, and environmental degradation formed a major theme in our analysis and recommendations. What is needed now is a new era of economic growth - growth that is forceful and at the same time socially and environmentally sustainable."

The issue is how to translate the above mentioned missions of creating a sustainable society to a practical tool for designers, engineers and architects. One of the key aspects of the required de-linking of economy and ecology is the fact that products and services need to have a low ratio of their eco-costs and their value (EVR).

1.3 Eco-costs 2007, a single indicator for LCA

The eco-costs method is used in LCIA to express the amount of environmental burden of a product or service, on the basis of prevention of that burden. Eco-costs are the costs which should be made to reduce the environmental pollution and material depletion in our economy to a level which is in line with the carrying capacity of our earth (the so-called 'no-effect level'). As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains (Life Cycle Costs). The eco-costs should be regarded as hidden obligations.

The eco-costs of products are based on the sum of the marginal prevention costs ('end of pipe" as well as system integrated) during the life cycle (cradle to grave as well as cradle to cradle) for toxic emissions, material depletion, energy consumption and conversion of land. The structure of the calculation system is depicted in Figure 1.2. The advantage of eco-costs is that they are expressed in a standardized monetary value (€) which appears to be easily understood 'by instinct'. The calculation is transparent and relatively easy, compared to damage based models which have the disadvantage of extremely complex calculations with subjective weighting of the various aspects contributing to the overall environmental burden (Bengtsson and Steen, 2000, Finnveden , 2000).

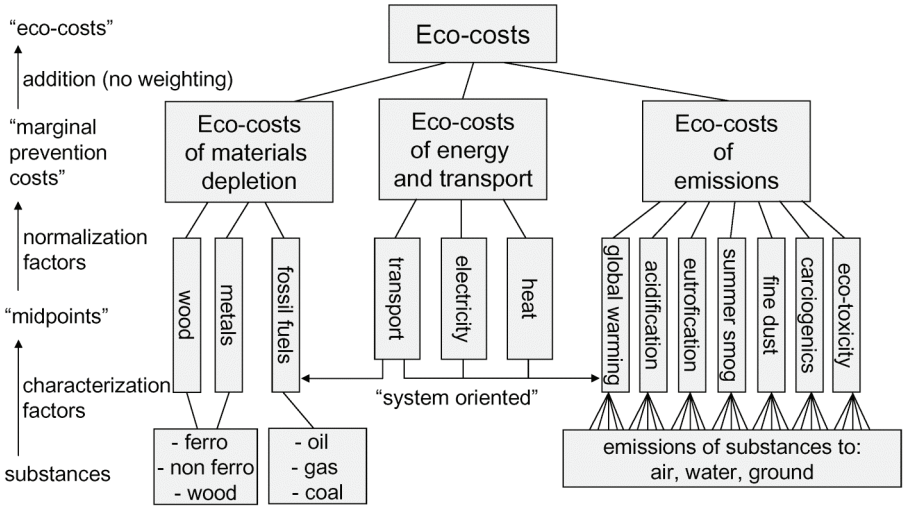

Figure 1.2. Calculation structure of the eco-costs 2007.

The method of the eco-costs 2007 comprises tables of over 3000 emissions, and has been made operational by special database for Simapro, based on LCIs from Ecoinvent v2 and Idemat 2008 (over 5000 materials and processes), and a database for CES (Cambridge Engineering Selector). Excel look-up tables are provided at www.ecocostsvalue.com.

Note. Prevention measures will decrease the costs of the damage, related to environmental pollution, e.g. damage costs related to human health problems (Holland, Watkiss, 2003). The savings which are a result of the prevention measures are of the same order of magnitude as the costs of prevention. So the total effect of prevention measures on our society is that it results in a better environment at virtually no extra costs, since costs of prevention and costs of savings will level out.

1.4 Perceived Customer Value

To understand the EVR model, and to understand the de-linking of economy and ecology, it is essential to understand the concept of 'perceived customer value'[2] in modern management. Each product and each service has 3 economic dimensions: the costs, the price and the socio-economic (market) value. See Figure 1.3. These dimensions have all money (e.g. €, $, etc.) as unit, but must strictly be kept separate (it is obvious that adding components of the cost to the price has no practical meaning at all; the same applies to the value).

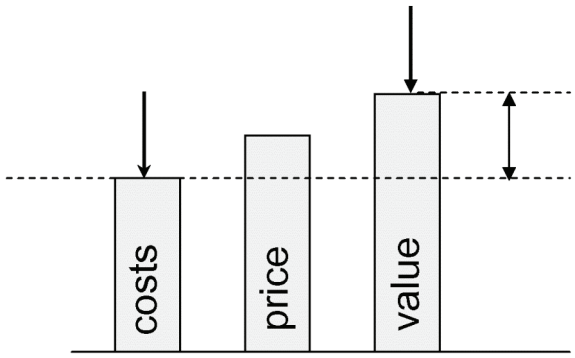

Figure 1.3. The costs, the price and the value of a product or service.

Note: value = product quality + service quality + image

In the modern management approach, the strategic focus is on the ratio of value and costs. The value is normally a bit higher than the price ('a buyers market'), but might also be a bit lower than the price ('a sellers market'). In the EVR model we take the

[2] 'perceived customer value' might be defined as "the use and fun which is expected after the purchase, as seen through the eyes of the customer"

average case where the value is the 'fair price', which is the price which the average buyer in the specific market niche is prepared to pay.
In the classical management paradigm, higher value (´quality´) leads always to higher costs. In the modern management paradigm that is not the case: there are many management techniques that lead to a better value/costs ratio. Examples are: logistics (better delivery at lower stock levels), complaint management (satisfied customers with less claims), waste and quality management (less materials, better quality). All these examples – there are many more in the field of Total Quality Management and Continuous Improvement - lead to more value at less costs. This is called 'the double objective' for managers and opens new perspectives to support eco-efficiency (it supports the first part of the eco-efficiency definition of the WBCSD). Note that this modern management philosophy is much more than just 'adding services' to existing products. It is about carefully improving the quality of products and services (as perceived by the customer) by eliminating the 'non value added' energy, materials and work.
A fact is that these modern management techniques not always lead to better eco-efficiency (e.g. the use of pesticides in agriculture results in a better value/costs ratio but not in a better level of environmental protection). That is why the aforementioned definition of eco-efficiency of the WBCSD adds *"… while progressively reducing ecological impacts …"*.
For this reason, companies which aim at good governance must make sure that their products have low eco-costs. LCA is here an indispensable tool.
More information on the dynamic aspects of perceived customer are given in Appendices 5, 6 and 7.

1.5 The Ecocosts-Value Ratio (EVR)

The Ecocosts/Value Ratio, EVR, is an indicator which fulfills 3 different functions:

1. It is an indicator for sustainability in LCA (additional to the eco-costs) in cases where the quality of products (with the same functionality) differs.
2. It is an indicator which is relevant to corporate strategies and governmental policies: it links the consumer side with the production side (see Chapter 5).
3. It is a parameter in the so-called *economic allocation* of LCA calculations (see Section 3.5).

The aim of an LCA is often to compare two products (or services). A prerequisite is then that the two products have the same functionality *and the same quality* (in the broad sense of the word).
In practice, however, new innovative 'green' designs often have the same functionality, but differ from the classical design. In such cases the quality is not the same. It is a widespread misunderstanding that the design with the lowest eco-costs (or millipoints, or carbon footprint) is always the best choice in terms of sustainability. When the eco-

costs of the new design are lower and the quality is better, there is no doubt that the new design is more sustainable. However, when the quality of the new design is lower, it remains to be seen which design alternative is the best choice in terms of sustainability.
In cases where the quality differs, the Ecocosts/Value Ratio, EVR, appears to be a better indicator for sustainability. This is because "value" (fair price) is a good indicator for the quality in the broad sense.

The EVR is a so-called E/E indicator, which means that it is an indicator to describe the eco-efficiency of a product and/or service. The EVR is a dimensionless number which indicates to what extent a (design of a) product contributes to the de-linking of economy and ecology. Most of the other E/E indicators which are proposed in literature, divide eco-burden by costs (or the other way around). The EVR, however divides the eco-costs by customer value, which brings the customer behaviour into the equation.
In the model of the EVR, a product (and service) has 3 separate dimensions: the costs, the eco-costs and the value. See Figure 1.4. These dimensions have all a monetary unit (e.g. €, $, etc.), but must strictly be kept separate (it is obvious that adding components of the cost to the value has no practical meaning at all; the same applies to the eco-costs).

There is a consumer's side of the de-linking of economy and ecology. Under the assumption that most of the households spend in their life what they earn in their life, the total EVR of the spending of households is the key towards sustainability. Only when this total EVR of the spending gets lower, the eco-costs related to the total spending can be reduced even at a higher level of spending. There are two ways of achieving this:

1. at the production side: the improvement of eco-efficiency ('lowering EVR') of products and services by the industry
2. at the consumer's side: the change of lifestyle of customers in the direction of 'low EVR' products.

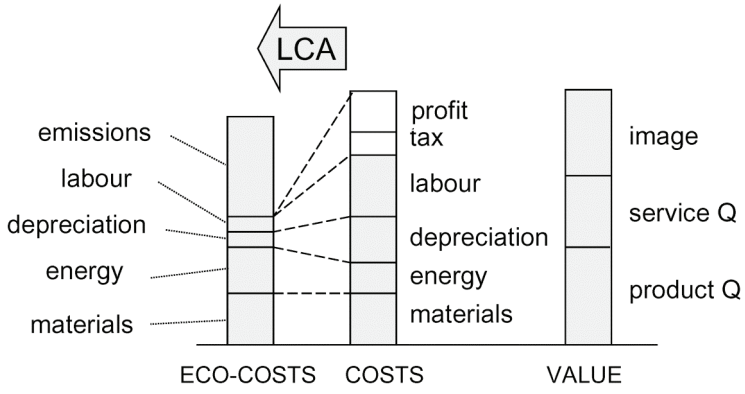

Figure 1.4. The value, the costs and the eco-costs of a product and/or service.

The EVR can also act as a parameter for economic allocation in LCA calculations, especially for services (eco-costs per € instead of eco-costs per kg). The issue is that services are characterized by shared use of facilities (for transport, offices, equipment etc.) which is complicating the LCA, since materials and emissions are shared as well. Materials and emissions must then be allocated to a specific service in line with the economic importance of that specific service, the so-called 'economic allocation' in LCA.

1.6 A new data set: the eco-costs 2007

The original eco-costs 1999 were based on characterisation tables of the eco-indicator 95 and prevention costs of RIVM of 1997 (Delink and Van der Woerd, 1997).
After the first set of publications, the basic data have been discussed extensively, and were adapted to new studies and tables from literature.
The characterisation tables in the eco-costs 2007 system are:

- IPPC 2007, 100 years, for greenhouse gases
- CML-2, for acidification, eutrification and summer smog (photochemical oxidation)
- IMPACT 2002+, for aquatic eco-toxicity (inc. heavy metals), fine dust (was winter smog) and carcinogens

Although calculations on marginal prevention costs only change with monetary inflation (see Appendix 3), the calculation on the prevention costs of summer smog has been revised entirely since new data came available (Cronenberg, 2000), and since two effects influenced the calculations considerably: the innovations in water based paint systems and the innovations in motor management in the automotive industry. Both innovations resulted in a drastic change of the curve of prevention costs, and therefore a drastic change in the marginal prevention costs. The marginal prevention costs of carcinogens has been changed as well, based on the aforementioned study on summer smog.
The calculations of prevention costs of greenhouse gases of ECN were checked with an extensive study on the costs of wind parks at the sea[3] by the University of Leuven (Van Capellen, 2005), but there was no need for a change other than the monetary inflation.
Note. Aquatic eco-toxicity (including heavy metals), fine dust, and carcinogens are rather problematic in LCA, since there effects are non-linear (LCA is inherently a linear calculation system) and often specific for the typical local situation. See also Appendix 2. These emissions, however, are kept within the eco-costs system to maintain the 'signalling function' (showing that the toxicity of the product is OK in the Life Cycle).

[3] The eco-costs (marginal prevention costs) of greenhouse gases (CO_2) are determined by the costs of substitution of electricity from coal fired power plants by electricity of windmill parks at the sea. The reason why will be explained in Chapter 2.

1.7 The structure of this book

This book is a compilation of a series of publications in scientific journals. Exact reference data of the original publication is provided at the first page of each chapter. The text in the book is nearly a verbatim copy of the original text, however, the numbers and tables are new (updated) with respect to the ecocosts 2007.
The advantage of the verbatim versions is that each chapter of this book can be read 'stand-alone'. The disadvantage is that some general information is repeated in each chapter.
The reference lists of literature have been combined.

Since the Doctorate Thesis contains more information than the articles in the scientific journals, some additional information is provided in the Appendices of this book. For each Appendix the reference page(s) of the Doctorate Thesis are provided. Sometimes the text in this book is a verbatim copy of the Thesis, in some Appendices the text of the Thesis has been shortened.