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Communicating the eco-efficiency of products and services by means of the eco-costs/value model

Joost G. Vogtländer *, Arianne Bijma, Han C. Brezet

Delft University of Technology, Faculty Design Construction and Production, Section Design for Sustainability, Jaffalaan 9, NL-2628BX Delft, The Netherlands

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Abstract

At the Delft University of Technology, a new model has been developed to describe the sustainability of products, the 'EVR model'. This model comprises two concepts:

- the 'virtual eco-costs' as a LCA-based single indicator for environmental impact
- the EVR (Eco-costs/Value Ratio) as an indicator for eco-efficiency

In this publication, an experiment is described to test whether the EVR model leads to a good understanding of the eco-efficiency, of a product–service combination. In this experiment three separate groups of 8-11 people were asked to rank four alternative solutions of a product–service system (the after sales service and the maintenance service of an induction plate cooker) both in terms of sustainability and of general preference. The three respective groups were:

- customers (among whom representatives of consumer organizations)
- business representatives from the manufacturing company of the induction plate cookers
- governmental representatives (employees of the Dutch ministries of environmental affairs and economic affairs, and of the Dutch provinces as well as consultants involved in governmental policies), all experts in the field of sustainability

The basic idea was to ask each group to rank the four alternatives after three levels of information input:

Level 1: basic explanation of the four alternatives. Some major features and characteristics such as price were given, but no environmental data.
Level 2: on explanation of an LCA of the four alternatives, given in nine impact classes and the Eco-indicator 95.
Level 3: an explanation of the EVR model and the EVR data of the four alternatives.

Each time the group was asked to rank the proposed alternatives in terms of expected environmental performance and of 'best choice in general' ('Which system would you have bought in a real life situation?').

From the experiments it can be concluded that:

- The concept of eco-costs was accepted by the majority of the non-experts: they based their ranking on it. and they preferred it rather than direct LCA output or the damage based eco-indicator 95 data.
- The environmental experts in the governmental group did not directly accept the concept of eco-costs model (they wanted in depth information first); they tended to stick to their existing knowledge of LCA data and the Eco-indicator 95.

* Corresponding author.
E-mail address: joost.vogtlander@aimingbetter.nl (J.G. Vogtländer).

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- 'Overall' preferences of the customers and business representatives were primarily ranked on the 'perceived value'/costs ratio of the product–service combination; the sustainability of the product–service combination played a secondary role.

Keywords: Eco-costs; Eco-efficiency; Eco-indicator 95; EVR; LCA; Product–service systems; PSS; Single indicator; Sustainability

1. Introduction

In moving towards a sustainable society, three stakeholder groups have a major role:

- consumers/citizens, who must shift their expenditures towards products with a low environmental burden
- companies, which must create product–service combinations with a low environmental burden
- governments, which must create regulations and new systems for tax and subsidies that support the required transition

One of the major issues is that of communication between these three stakeholders. A good interaction between stakeholder groups requires good communication on the subject, which requires all stakeholders to 'speak the same language'.

Currently there seems to be a communication gap between environmental specialists and non-specialists (the majority of the stakeholders). Environmental specialists regularly try to make the situation clear by showing the results of LCAs and the *environmental impacts (in terms of damage)* of products and processes. However results of an LCA are complex and hard to understand (environmental specialists tend to stress that as well). Many discussions in science about impacts, the complexity of the calculations, and problems with setting priorities, make stakeholders aware of the imminent problems, but do not make clear how to tackle the problem [1–4].

In terms of providing data on the results of an LCA, there seem to be the following options:

- the full LCA data, which satisfies the LCA specialists, but which is too complex for designers and business managers (so they cannot base there decisions on such data sets)
- the result of one class of emissions only (e.g. in kg CO_2 equivalent), which is clear to designers and business managers, but which is unsatisfactory since environmental problems can be obscured by redesigns which shift the problem towards other classes of pollution
- one single indicator in terms of 'points' for emissions and materials depletion (e.g. eco-indicator '95 and '99)[1], which is clear to designers, but which is opposed by many LCA specialists because of difficulties in weighing the different kind of damage types (classes).
- one single indicator in terms of money (e.g. the EPS indicator), which appeals to business managers, but which is opposed by many LCA specialists

At the Delft University of Technology, a model has been developed to assess the so called 'eco-efficiency' of products and services[2]. This model is based on the Life Cycle Analysis (LCA) methodology as defined in the IS0 14040 and 14041, and is called the Eco-costs/Value Ratio (EVR) model. It is a decision support tool for designers of sustainable product–service combinations and for business managers to support product portfolio management and marketing strategies.

Right from the start of the development of this new model, it was felt that a model based on *prevention costs* (instead of the existing damage based models for single indicators), would have good prospects for communication, but that had to be tested first.

Therefore, it was decided to test the way each of the stakeholders (consumers, business managers and governmental representatives) use information to make their decisions. An experiment was designed to find out what kind of preferences prevail in terms of data on the results of LCAs, and how these data influence the final choice (to buy a product–service combination in a real life situation).

During the experiment, the focus was primarily on *how* the participants made their choices, and on what information they would base those choices.

The participants were given the impression that the aim

[1] The experiment was held in June 1999. At that time the eco-indicator '99 had not yet been published. It is the impression, however, that the outcome of the experiment would not have been significantly different when the eco-indicator '99 had been applied instead of the eco-indicator '95.

[2] In 1995, the World Business Council for Sustainable Development (www.wbcsd.org) described the role for industry in their definition of 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.

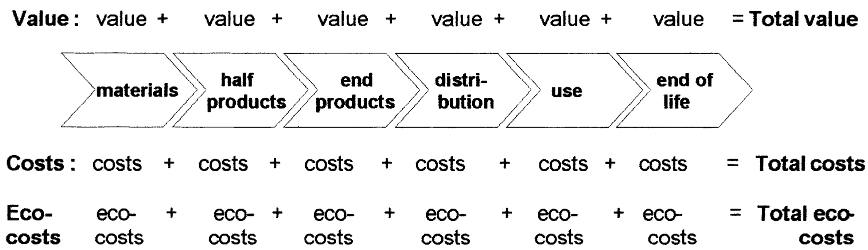

Fig. 1. The basic idea of combining the economic and ecological chain: 'the EVR chain'.

of the experiment was to make the right selection out of four alternative solutions for a service function (the maintenance of an induction plate cooker), as they would have done in a real life situation. In reality, however, it was not so important what their choice was, but how they made their choice and based on what LCA data.

The primary aim of the experiment was to find out which LCA data set was preferred by the participants: data on the nine classes of emissions(e.g. kg CO_2 equivalent), the eco-indicator '95, or the eco-costs from the EVR model.

The secondary aim was to find out whether, and how, the final purchase decision was influenced by the environmental data.

2. Part I: the eco-costs/value ratio model

2.1. The eco-costs

The basic idea of the EVR (Eco-costs/Value Ratio) model is to link the 'value chain' [5] to the 'ecological product chain'. In the value chain, the added value (in terms of money) and the added costs are determined for each step of the product 'from cradle to grave'. Similarly, the ecological burden of each step in the product chain is expressed in terms of money, the so called virtual eco-costs '99 (in short eco-costs). See Fig. 1.

The eco-costs are 'virtual' costs: these costs are related to measures which have to be taken to make, use and recycle a product '*in line with the earth's estimated carrying capacity*' (see [2]). These costs have been estimated on the basis of technical measures to *prevent* pollution and depletion of materials and energy to a level which is sufficient to make our society sustainable.

Since our society is yet far from sustainable, the eco-costs are 'virtual': they have been estimated on a 'what if' basis. They are not yet fully integrated in the current costs of the product chain (the current Life Cycle Costs)[3].

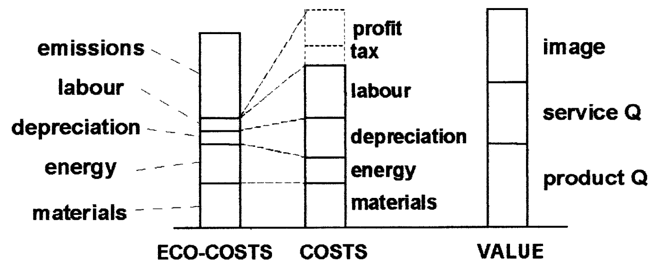

Fig. 2. The decomposition of 'virtual eco-costs', costs and value of a product.

The ratio of eco-cost and value[4], the so called Eco-costs/Value Ratio, EVR, can be defined for each step in the chain. For the total life cycle as well as for a part of the chain, the eco-costs, the costs and the value can be calculated, as depicted in Fig. 2.

The five components of the eco-costs have been defined as three 'direct' components plus two 'indirect' components, see Table 1. Based on the detailed cost structure of the product, the eco-costs can be calculated for each cost element, applying the LCA methodology as defined in IS0 14040 and 14041. A detailed description on the way this is to be done is given in [9].

One of the main elements of the eco-costs are the 'pollution prevention costs' (direct component 1). How these costs are calculated will be described in the next section.

2.2. Calculation of the pollution prevention costs

The pollution prevention costs are to be calculated in four steps:

1. LCA calculation according to the current standards (IS0 14041)
2. Classification of the emissions in seven classes of pollution (acidification, eutrophication, heavy metals, carciogenics, summer smog, winter smog, global warming)

[3] The concept of the 'virtual eco-costs' is slightly different from the concept of the 'external costs'. The external costs are related to *damage* to our environment. The virtual eco-costs are related to the ('marginal') *prevention* costs, which are required to bring our economy into a state which is sustainable. What both type of costs have in common, is that they are not incorporated in the current economic costs of products and services.

[4] Within the business chain, the value equals the market price. Note that the cost for the buyer equals the value for the seller in the business chain. The situation in the Use phase and in the End of Life phase is slightly different. From the consumers point of view the value equals the 'fair price' [6,7], which reflects the perceived benefit after the purchase. In the End of Life phase the value might be negative.

Table 1
The main five components of the eco-costs

Direct components	Indirect components
1. virtual pollution prevention costs, being the costs required to reduce the *emissions* of the production processes to a sustainable level [8]	1. eco-costs of *depreciation*, being the eco-costs related to the use of equipment, buildings, etc.
2. eco-costs of *energy*, being the price for renewable energy sources	2. eco-costs of *labour*, being the eco-costs related to labour, such as commuting and the use of the office (building, heating, lighting, electricity for computers, paper, office products, etc.)
3. *materials* depletion costs, being (costs of raw materials)×$(1-\alpha)$, where α is the recycled fraction[a]	

[a] In theory, one must apply here the 'present market value' (discounted) of the 'sustainable alternative in the future' for the material which is depleted, according to the model of Hotelling [12]. For most of the materials, however, there is no reason to believe that this 'present discounted market value of the sustainable future alternative' deviates much from the current average material prices (examples: tin, copper, iron), since the functionality of these materials can be replaced by alternatives which are not more expensive for their specific functions. So the present price levels can be applied for 'costs of raw materials' in this formula. An exception is oil as a source for plastics. In the model, the costs for ethanol from biomass has been taken for the 'costs of raw materials' for plastics.

3. Characterization according to characterization multipliers as used in e.g. the eco-indicator '95, resulting in 'equivalent kilograms' per class of pollution
4. Multiplication of the data of step 3 with the 'prevention costs at the norm', being the marginal costs per kilogram of bringing back the pollution to a level '*in line with earth's carrying capacity*'

The following 'prevention costs at the norm' have been calculated for The Netherlands and Europe:

prevention of acidification:
6.40 Euro/kg (SO_x equivalent)
prevention of eutrophication:
3.05 Euro/kg (phosphate equivalent)
prevention of heavy metals:
680 Euro/kg (calculation based on Zn)
prevention of carciogenics:
12.3 Euro/kg (PAH equivalent)
prevention of summer smog:
50.0 Euro/kg (calculation based on VOC equivalent)
prevention of winter smog:
12.3 Euro/kg (calculation based on fine dust)
prevention of global warming:
0.114 Euro/kg (CO_2 equivalent)

These 'prevention costs at the norm' are based on the so called 'marginal prevention costs' of emissions. The way these marginal prevention costs are determined is depicted in Fig. 3. For each type of emission, the costs and the effects (in terms of less emissions) are accumulated for several prevention measures to be taken (a 'what if' calculation). At a certain point of the curve, the 'norm for sustainability' is reached. The marginal prevention costs are defined by the costs per kg reduction of the 'last' measure, depicted as line b.

The 'norms for sustainability' are based on the 'negligible risk levels' for concentrations (in air and in water) and the corresponding 'fate analyses' (the link between concentration and emissions). For further details on these prevention costs, see [8].

2.3. Implications of the EVR on product portfolio strategy

Progressively, industry is facing the slow but inevitable internalization of environmental costs which are currently external to the costs of production. The rate of this process is unpredictable, but the transformation process as such seems to be inevitable. The eco-costs of a product are a norm for the magnitude of the impact this trend of internalization might have on future product costs. The eco-costs/value ratio is therefore a measure for the sustainability (eco-efficiency) of a product (ref. [2]).

With regard to product portfolio management of companies, the EVR model shows the clear implications in the matrix for product–service systems of Fig. 4.

The basic idea of this product portfolio matrix is the fact that each product–service system is characterized by:

- its short term market potential: the value/costs ratio
- its long term market requirement: the EVR

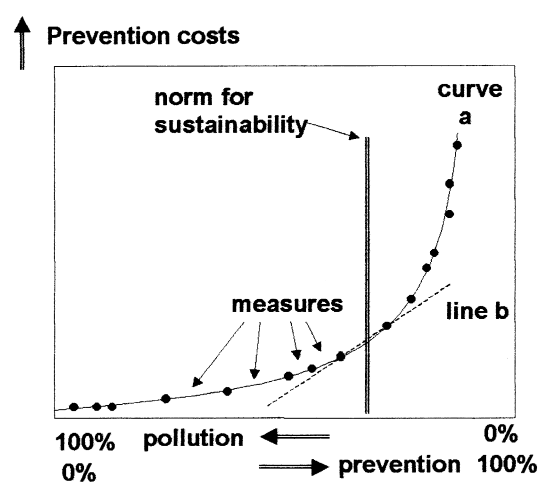

Fig. 3. The way the marginal prevention costs are calculated from emission prevention measures for a certain region.

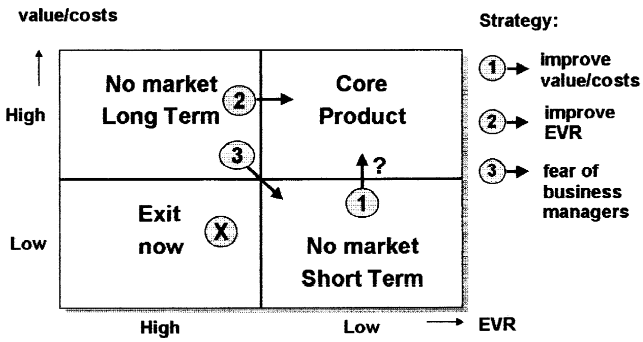

Fig. 4. Product portfolio matrix for product strategy of companies.

In terms of product strategy, the matrix results in four strategic directions:

1. enhance the value/costs ratio of a sustainable design with a sound EVR to make it fit for short term introduction in the market
2. enhance the EVR of current successful products to make it fit for future markets
3. make certain that direction 2 doesn't result in a lower value costs ratio in the implementation phase
4. abandon products that combine a low value/costs ratio with a high EVR

3. Part II: the experiment

3.1. The design of the experiment

The basic idea of the experiment was to provide the participants stepwise with more information on the environmental aspects of the four after sales concepts, and monitor whether the opinion of the participants would change as a reaction to this information and how.

The programme of one session had a duration of 4 h and comprised the steps shown in Fig. 5.

The experiment was led by an independent facilitator, and was held by means of the Group Decision Room Computer System of the University of Delft. The room is like a normal meeting room, however, each participant has his or her own computer terminal to type in the answers to the questions (for more information on this Group Decision Room Computer System and the way experiments are designed for this system, see [10]).

The advantage of such a computerized decision system is that the voting, ranking and comments are done anonymously, so without interference (influence) of the other participants. The comments were labelled in the computer with code names, in order to be able to track the individual comments and decisions throughout the session.

The disadvantage of such an approach of anonymous participants however is that specific characteristics of the individual participants (like age, education, etc.) were not known. It was only after the session that we realised (by studying the comments) that experts reacted differently in comparison with non-experts, causing major differences between the governmental group (100% experts) and the other groups (approx. 20% experts).

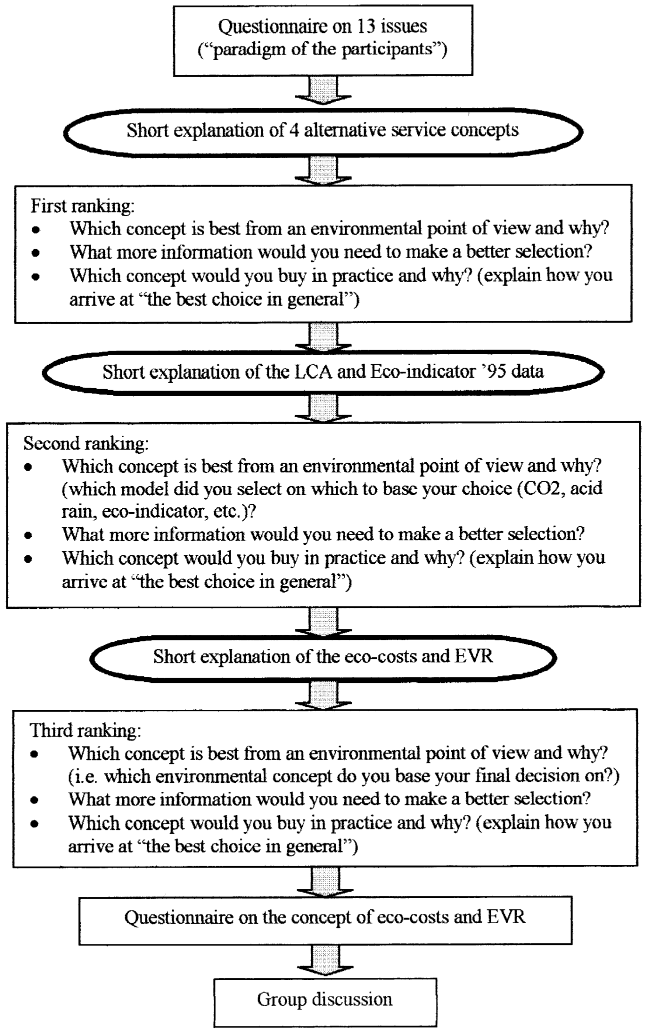

Fig. 5. The flow-chart of the experiment.

Although the real information on the environmental aspects is very complex by nature, the concepts were shown in an extremely short time span. Only 5 min to explain the basic concept of an LCA and the eco-indicator '95, 5 min to explain the concept of eco-costs (no explanation of how these costs are calculated) and less than 5 min for the EVR (eco-costs versus value charts). So especially on the EVR concepts, hardly any time was spent to reflect on it. Many aspects were 'thrown on the table' just to check what was 'understood intuitively'. Another motive to keep the explanation very short was to avoid a situation where participants would have got the feeling that the EVR was 'promoted'.

The three groups received the same information (so the information was not 'adapted' to the group). Only the final discussion was focussed on the primary interest of the group, and was therefore different for each session.

With regard to the first, second and third ranking of preferences (Fig. 5), the questions to be tested were:

- Do people change their preferences when they are confronted with data on sustainability? (Evaluated from the question, 'Which concept do you prefer in general?').
- Do people accept the outcome of a certain model of environmental calculations, after a very short description of the model? (Evaluated from the question, 'Which concept—of after sales service—is best from the environmental point of view?')
- Do people change their minds when they are confronted with the concept of eco-costs and EVR *after* being confronted with the concept of the eco-indicator '95? (They might become confused when they discover that there are more models to assess the sustainability of a product; do they switch their opinion within such a short time span? Do they prefer the eco-costs and do they accept it?)
- Do people feel that they need more information to choose (at each step of the programme), and if so what kind of information? (evaluated from the question, 'What more information do you need to make a better selection?')

3.2. Four concepts of after sales service and maintenance of an induction-plate cooker

To be able to conduct the experiment, four alternative product–service combinations were designed. The product chosen for this experiment is an induction-plate cooker, a 'high quality' product with a premium price (approx. 1800 Euro) which can be purchased with a 'full guarantee' for 10 years. See Fig. 6. The service which is chosen for the experiment is the after sales service with this product.

Fig. 6. The object of the study: an induction-plate cooker.

For the experiment we developed four different types of hypothetical service concepts, described below.

A. 'Conventional', being the classic type of after sales service (repair):

- in case of a break down, the client calls the company
- the telephone operator will ask what the problem is
- the after sales service planning department will schedule the local service engineer within 24 hours
- the logistic system will deliver the required parts overnight in the van of the service engineer
- the engineer is able to repair the induction plate cooker in 70% of the cases; in 30% of the cases he needs to visit a second time because he has not been able to repair the product the first time.

B. 'The first time right', being a situation where 100% of the cases are repaired the first time:

- by adding the right diagnostic software to the product, the telephone operator knows exactly what is wrong
- the planning department knows the repair time
- the logistic system will bring the right parts

Note: an induction plate cooker has already a lot of control software, so adding diagnostic software can be done relatively cheaply (4, 5 to 9 Euro extra per cooker, which is less than 0.5% of the price).

Major advantage: the client will not be disappointed and there will be less pollution since the service engineer will drive less kilometres.

C. 'Easy to repair by the client'

- the product will be of a modular design (easy clips, screws for click-on and plug-in)
- a repair guide on the web site and a help desk will guide the customer through repair actions
- ordering new parts (=modules) by e-mail or at the help desk, delivery by post next morning

Note: making the product modular is estimated to add 35 Euro per cooker to the sales price.

Major advantages: the client doesn't need to stay home for the service engineer, and there will be less pollution since there is no need for service engineer kilometres.

D. 'Designed for less maintenance', reducing maintenance by 60%

- it appears that 60% of all repairs is caused by the failure of two specific circuit boards
- it is possible to design these parts 'trouble free' either by adding back-up boards, or by heavy testing

Table 2
Indicative data on the costs of repair of an induction plate cooker

	Chance of repair in 10 yr (%)	Costs of service (a) (Euros)	Costs of parts (b) (Euros)	Total costs of repair (a)+(b) (Euros)	Extra costs of induction cooker (Euros)
Conventional	60	65	75	140	–
The first time right	60	50	75	125	4.5–9
Easy to repair by the client	60	–	80	80	35
Designed for less maintenance	24	50	75	125	180

- however the price for this solution is about 180 Euro (10% of the purchase price) extra.

Note: 'maintenance free' is not possible without a price increase of more than 50%.

Major advantage: reliable product; enhanced durability of the product.

3.3. The data on the four concepts

Data were derived from the existing situation of the after sales service. Based on this data, estimates were made on the alternative solutions such as the required additional personnel and investments for each department: the call centre, the logistic departments, the service engineers and the administration and 'overheads'. Furthermore operational data were gathered such as number of repairs per day per engineer, average kilometres per client, characteristics of the repairs, average costs of parts, etc. (see Table 2).

The LCA data of Figs. 7 and 8 were calculated by means of the Simapro computer program (www.pre.nl).

For the third part of the experiment, EVR data were calculated for the four alternatives and depicted in EVR charts.

Fig. 9 depicts the eco-costs and the costs of the various activities which are involved in the repair of the induction plate cooker in the conventional way (as described in the previous section):

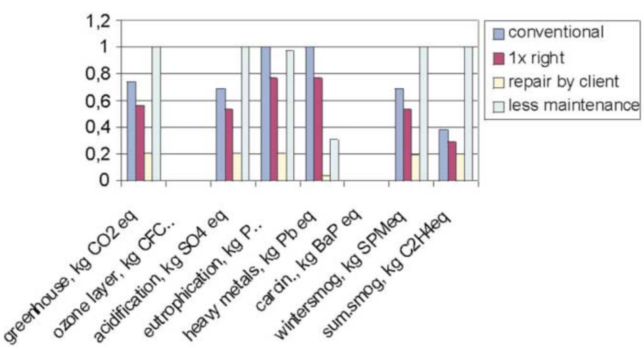

Fig. 7. The relative emissions of eight pollution classes for the four maintenance concepts.

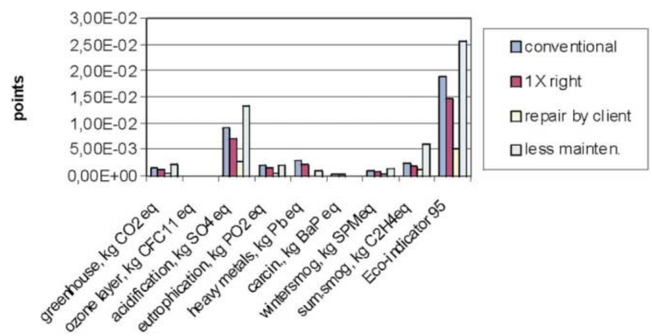

Fig. 8. The emissions in 'points' of the eco-indicator '95 for the four maintenance concepts.

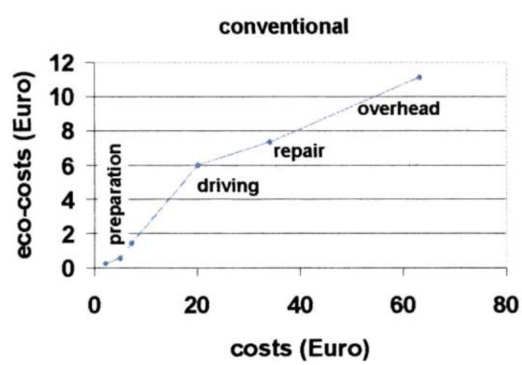

Fig. 9. The eco-costs versus costs chart of conventional repair of the induction- plate cooker.

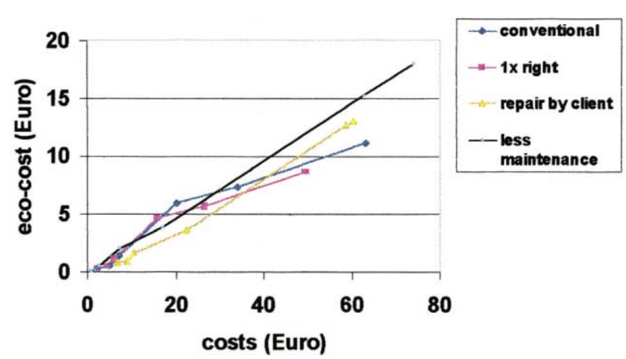

Fig. 10. The eco-costs versus costs chart of the four concepts of after sales service of the cooker.

- the *preparation*, including the call centre, the planning and the logistics of the parts
- *driving* to and from the client of the service engineer
- *repair* of the cooker at the home of the client
- the *overheads* of the organization

In Fig. 10 the eco-cost charts are shown for the four alternative concepts of after sales:

- for 'first time right' the savings are in driving, repair and overheads
- for 'repair by client' there is no driving and repair by the service engineer, but the cooker is more expensive and contains more material (the 'last leg' of the line)
- for 'less maintenance' there are 60% savings on the repair (first time right) but price of the cooker is 3–10% more expensive and contains more material (the 'last leg' of the line)

3.4. The results of the experiments

3.4.1. Ranking test of consumers group and the business representatives group

The results of the first, second and third ranking of preferences for the session with the consumers and the session with business representatives is depicted in Fig. 11(a,b) and 12(a,b).

The consumers group and the business representatives group were quite similar in their choices on ranking of 'best choice for the environment' (top score is 4; least score is 1), see Fig. 11(a) and 12(a). They both changed their opinion in each ranking session. They both started with the 'guts feel' that 'less maintenance' was better for the environment. In later ranking sessions they realised that there was a heavy penalty for it in the extra material required in the cooker.

Detailed analyses of the third ranking session of the consumers group, showed that only one out of the nine participants had chosen for the eco-indicator model instead of the eco-costs model on which to base their ranking (In the third ranking step it was explicitly asked to decide which environmental model would be used for the final choices). In the business group this was only one out of eight participants.

The difference of ranking on 'the best choice, general' between the two groups was also minor: the main difference is that the consumers ranked 'repair by client' higher than the business representatives.

In both groups 'the best choice, general' was only slightly influenced by the environmental information.

On the basis of the comments on the question why a certain alternative was chosen, it could be concluded that the environmental aspects play only a secondary role in the choice, as depicted in Fig. 13. When the value/price ratio already leads to a conclusive choice, customers do not take environmental aspects into consideration anymore. Only when there is no preference on the basis of value/price, do environmental issues help consumers make their final selection.

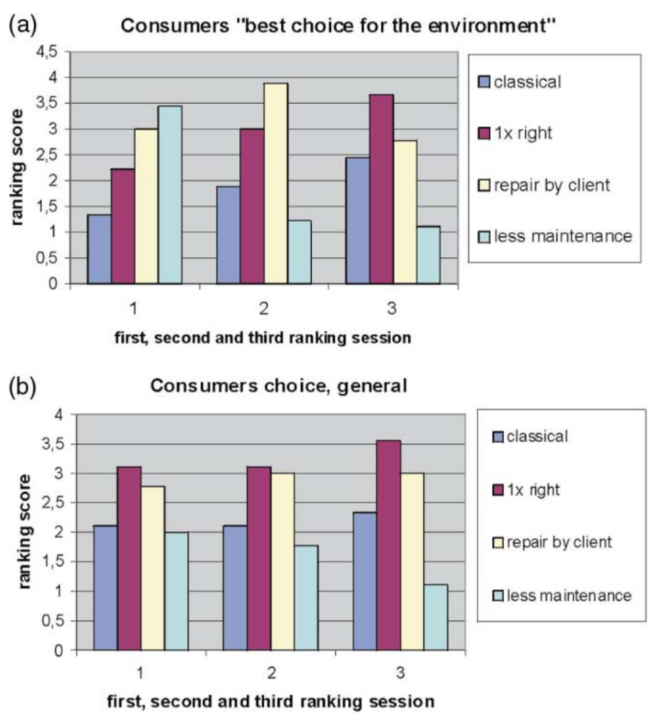

Fig. 11. (a) Consumers group environmental ranking. (b) Consumers group preferences.

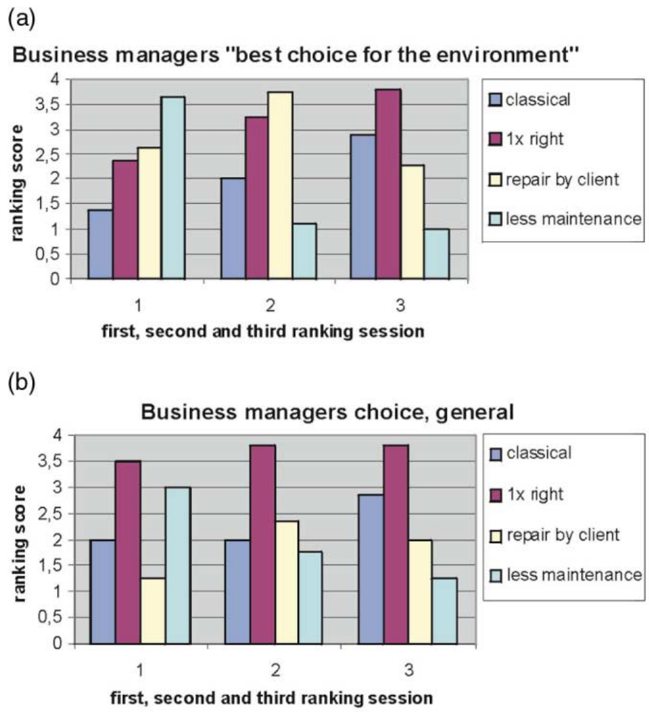

Fig. 12. (a) Business representatives group environmental ranking. (b) Business representatives preferences.

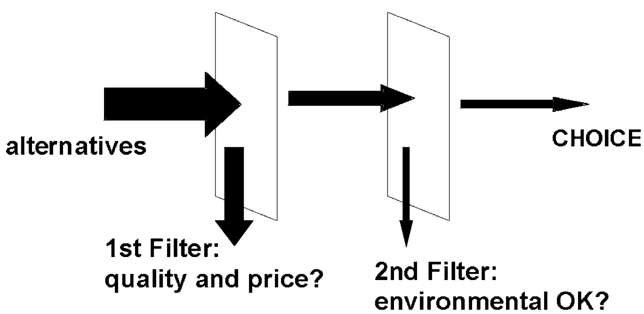

Fig. 13. Environmental data serve only as a second order filter in the decision of consumers (who are not specialists in the field of environmental issues).

3.4.2. *Ranking test of the group of governmental representatives*

The ranking test of the governmental group revealed a totally different pattern than the other two groups. See Fig. 14(a,b).

The major difference with the other groups is in the third ranking session of the question 'what is the best choice for the environment', Fig. 14(a): the third ranking does not differ significantly from the second ranking session. This means that the governmental representatives didn't use the eco-cost model as the preferred model. Analyses of the comments revealed that this seemed to be related with the fact that the participants were all experts in the field of sustainability, and were already acquainted with the LCA theories and with the eco-indicator '95 model. Only three out of 11 participants used the EVR chart to make the third ranking.

Furthermore, they tend (as most environmental experts do) to 'place sustainability above economy' for their personal purchase decisions, so the 'double filter model' of Fig. 14 did not apply to this group.

Since three out of 11 participants used the eco-cost versus cost chart to make the third ranking, the comments of the eight participants who preferred the eco-indicator '95 data were analysed. People who rejected the new model fell into one of the four following categories:

- I don't accept a monetary calculation since it is not allowed to compare ecology with economy; the choice for ecology is a fundamental one, regardless of the economic consequences to reach sustainability
- I see a new method which might be interesting, but I don't see yet the consequences of the model, so I reject it for the time being
- I want to know the details of the model first before I can accept it
- I am used to the eco-indicator '95, so I don't see why I should accept a new model

4. Conclusions

In order to reach a sustainable society it is important that government, business and consumers understand the concept of eco-efficiency. For this they need information

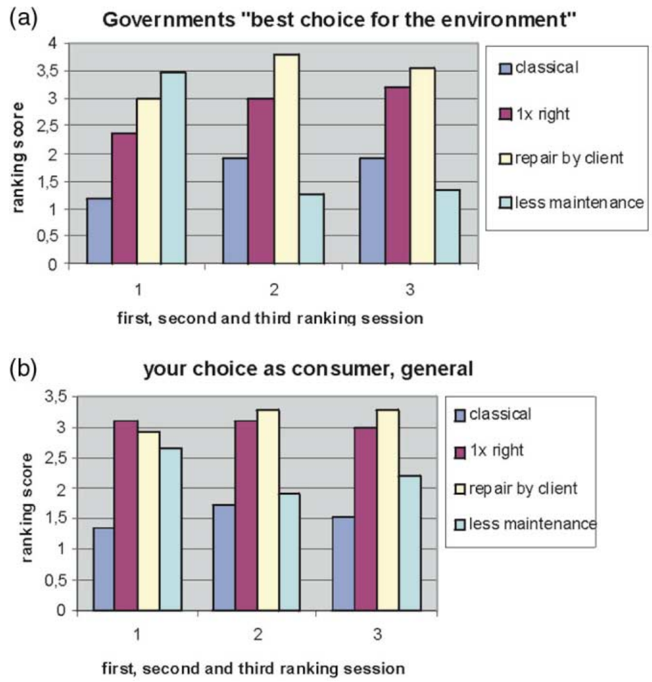

Fig. 14. (a) Government group environmental Ranking. (b) Government group preferences.

on which to base their decisions. Current environmental information, like LCA, fails to provide the answers in the right form to stakeholders in terms of decision support. The new eco-costs/value model aims to solve this problem but still needs to be communicated to the stakeholders and understood and accepted by them. The experiment revealed that the consumers and business representatives (non-experts) accepted the new model, even after a short explanation. They accepted it intuitively on the general philosophy, without a real understanding of the complete model. They understood the idea of eco-costs and the general meaning of the EVR (Eco-costs Value Ratio).

The government representatives (experts), on the other hand, did not accept the new model and stuck with the Eco-indicator '95 information, which was given earlier during the experiment. They did not see the need for a new model (they were specialists after all, not having trouble with LCA data) or did not accept the monetary nature of the model or had many questions before they could accept it. According to the theory of diffusion of innovation [11], it is common that expert groups stick to existing theories, rather than accepting new ideas. Rogers' studies revealed that these groups can be convinced only by 'opinion leaders' in their own profession.

The general impression of the whole experiment is that:

- consumers and business managers seem to be helped in their decisions concerning the environment by a single indicator for LCAs; a single indicator in terms of money (costs) has more appeal to them than a single indicator in 'points'
- the aspect of sustainability plays hardly any role in the decision when a consumer has a strong preference (based on other aspects) for a certain product type
- however the aspect of sustainability can play a quite important role in the decision when there is no preference on other grounds

This suggests that a real 'breakthrough' (in terms of impact on sustainability) in green marketing can be expected only when the aspect of sustainability is dealt with in terms of the 'second order filter' of Fig. 13. Sustainability can be made the distinguishing factor of choice, especially for commodity products and services (note that maintenance is a 'commodity service'). A precondition is that sustainability must be communicated in terms of a reliable indicator (where possible together with a certification system), preferably in terms of money.

It is recommended to test the above conclusions on a bigger, randomly selected, group of people.

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