COMBINING ECOLABELING AND MULTI CRITERIA METHOD TO MAKE AN ENVIRONMENTALLY SOUND EQUIPMENT PURCHASING DECISION

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ABSTRACT

The article focuses on a multi criteria method known as Analytical Hierarchy Process (AHP) for selection of the refrigerator for a home use. The authors suggest designing the hierarchy of criteria based on the concept of sustainable development and on criteria originating from the ecolabeling programs. The physiological rationalization of AHP as well as the problems of introducing into the analysis the economical criteria are also discussed. The ecolabeling criteria are based on the “Nordic Swan” program.

The analysis is conducted using the AHP-HIPRE software. The data for the analysis are the real data obtained from the leading producers and the weights are assigned by the authors. The sensitivity analysis of the obtained results is also presented.

KEYWORDS

Ecolabeling, multi criteria analysis, AHP, sustainable development

INTRODUCTION

Any decision maker, consciously or unconsciously, always applies a cost-benefit analysis method trying to find a solution which in the best way meets the selected criterion, or accepting the fact that there are many criteria, tries to find a compromise solution. The second approach means that one of multi criteria methods of decision making is applied. Cost-benefit analysis gives a single and clear answer to the problem, but leaves the decision-maker with the feeling that very many parameters of the selected products or analyzed options were not taken into consideration. On the other hand, applying the multi criteria method requires introduction of many evaluation criteria leading to less clear picture of the considered options. There is an extensive literature on this subject. [1-6].

When applying the multi criteria method firstly the decision maker has to select the method of analysis, and secondly, develop the evaluation criteria. There are many multi criteria methods, but thanks to its simplicity, versatility, and scientific background a method called Analytic Hierarchy Process (AHP) becomes recently very popular.[7-10] The fact that this developed in the ‘70s by T.L. Saaty [11-12], USA selection method can be implemented using a free software/shareware ads to its popularity (Expert Choice, HIPRE [13]). The article presents the AHP method and suggests the development of criteria for analysis using the environmental program of ecolabeling. The selection of refrigerator is presented as a case study.

BRIEF DESCRIPTION OF THE ANALYTIC HIERARCHY PROCESS

Psychological fundamentals of AHP method are as follows:

- Humans prefer to compare in form of dimensionless ratios (not differentiate), and are able to compare up to seven objects simultaneously,
- Humans see the world as a hierarchy of goals with relations,
- Human's reactions to impulses are more logarithmic than linear,
- All judgments are based on preferences.

Based on these fundamentals the AHP selection method was created. The method is executed in four stages:

- Developing the criteria of evaluation organized in hierarchical order,
- Assigning the weights for each criteria by pair wise comparison,
- Evaluation of alternative solutions using the developed criteria by pair wise comparison or using the directly obtained evaluation data,
- Calculating the final score of each alternative as a sum of products of weights and alternatives performance in each evaluating category.

The used criteria can be both descriptive (for example: design) or measurable (for example: price). Sometimes a decision maker wants the criteria to reach maximum value (efficiency) and sometimes minimal value of the criterion is the best (price).

One of the objections to the AHP method is a lack of scientific background how to create the hierarchy of evaluation criteria, and different evaluation hierarchies can lead to different evaluation results. Additionally, there is a problem that sometimes criteria can be selected in such a way that the same specific performance of alternatives is evaluated several times by different criteria. On the top of it, the decision makers very often lack technical knowledge about the evaluated alternative solutions and have to rely on the information provided by the producer's representatives which are not always reliable. To avoid all these problems and errors a new method of building the hierarchy of criteria is proposed. This method suggests to build the hierarchy of evaluation criteria based on the principle of sustainable development and to measure the environmental performance using criteria developed for the ecolabeling programs.

ECOLABELING AS A BASIS FOR CRITERIA SELECTION

The idea of ecolabeling is based on the principle that consumers are looking for products which are really environment friendly, and having a choice, they will choose environment friendly products even accepting higher price. On the other hand, producers knowing the consumers' preferences are ready to deliver such products if products' quality is objectively confirmed. To allow such objective quality check the independent certifying organizations set up very specific criteria, unique for specific groups of products. The produces can voluntarily apply for an ecolabel presenting their products for certification. If the products meet the criteria, and the producers pay the fee, and has a privilege to display the ecolabel sing on the product for a certain period of time, while the certifying organization undertakes the responsibility to start product supporting campaign. Both sides hope for the favorable consumers' response which leads to lower burden on the environment.

Different NGOs started ecological labelling of products in the ’70s. The main criterion was the energy consumption during the product’s production and operation. One of the first countries with the ecolabeling programs were Germany (The Blue Angel, 1978), Canada (Environmental Choice Label Scheme, 1988) and the Nordic countries (Nordic Swan, 1989). The European Union started its own program in 1992 (Daisy). The example of four European ecolabels presents Fig 1.

Figure 1. Examples of ecolabel signs in the EU

CRITERIA OF THE NORDIC SWAN ECOLABELING PROGRAM IN REFRIGERATORS SELECTION

The Nordic Ecolabel – Swan – is the official Ecolabel of the Nordic countries and was established in 1989 by the Nordic Council of Ministers (a geo-political, inter-parliamentary forum for co-operation between the Nordic countries) with the purpose of providing a voluntary environmental labelling scheme that would contribute to a sustainable consumption [14]. It is seen as simple marketing tool that is a guarantee that products have fulfilled stringent environmental and climate criteria.

The Swan („Svanen”) is one of the most recognisable eco-signs. The certification procedure is highly respected, for its complexity and objectivity. The certification procedure is carried out by independent body which takes into account both the final product and the production process. The Nordic ecolabeling requirements for refrigerators and freezers focus mainly on aspects of energy conservation, minimal impact on ozone layer and global warming, and amount of harmful substances used during the production. Also the noise level and recycling properties of final products and package is evaluated.

The requirements for Nordic Ecolabeling of refrigerators and freezers are almost identical to the Commission Decision of 6 April 2004 (valid until 31 May 2008) establishing revised ecological criteria for the award of the Community ecolabel for refrigerators. The Nordic Ecolabel criteria differ in requirement levels regarding flame retardants, life time extension and requirements to analysis laboratories and test institutions [15].
The list of the main Nordic Swan ecolabeling criteria with their description which can be used for the AHP analysis is as follows:

➢ ***ENERGY***

Energy savings – The refrigerator/freezer must have an energy efficiency class of A+ or higher as defined in Directive 94/2/EC [16] as last amended by Directive 2003/66/EC with regard to energy labeling of household refrigerating appliances. Complete test report from the measurement of energy consumption and calculation of the energy efficiency index (EEI) must be enclosed as documentation demonstrating fulfillment of the requirements.

➢ ***REFRIGERANTS AND FOAMING AGENTS***

- ***Ozone depletion potential (ODP) of refrigerants and foaming agents*** – The refrigerants in the refrigerating circuit and foaming agents used for the insulation of the appliance shall have an ozone depletion potential equal to zero. The use of CFCs and HCFCs as refrigerants and for the production of foaming agents in new equipment and their placing on the market is not permitted under Regulation 2037/2000/EC as last amended by Directive 2038/2000/EC [17] with regard to substances that deplete the ozone layer. As a proof of requirement fulfillment a list of refrigerants and foaming agents that are used in the appliance as well as a declaration from the producer/supplier of the refrigerants and foaming agents is needed.

- ***Global warming potential (GWP)*** – The refrigerants in the refrigerating circuit and foaming agents used for the insulation of the appliance, shall have a global warming potential equal to, or lower than 15 (rated as CO_2 equivalents over a period of 100 years). As a proof of requirement fulfillment a list of refrigerants and foaming agents that are used in the appliance as well as a declaration from the producer/supplier of the refrigerants and foaming agents is needed.

➢ ***THE CONSTRUCTION OF THE APPLIANCE***

- ***Take-back and recycling*** – The manufacturer shall offer confirmed by the certificate, free of charge, the take-back for recycling of the appliance and of components being replaced, except for items contaminated by users (e.g. appliances originating from medical or chemical establishments). The requirement is applicable in the Nordic countries where the Nordic Ecolabelled refrigerator/freezer is being marketed.

- ***Design*** – The product must be designed so that at least 75% by weight of the apparatus can be recycled in accordance with the 2002/96/EC (WEEE) directive [18]. The certificate is required.

According to Article 4 of the WEEE directive, this type of product must be simple to reuse and the materials must be simple to recycle. This means that joints must be easy to find and access, electronic components must be easy to find and remove, the product must be easy to disassemble using common standard tools, and it must be possible to separate out incompatible and hazardous materials.

- ***Marking of plastic parts*** **–** Plastic parts heavier than 50 grams shall have a permanent marking identifying the material, in conformity with ISO 11469 [19]. Certificate that the requirement is fulfilled is needed. Excluded from this criterion are extruded plastic parts.

- ***Flame retardants in plastic parts*** **–** Plastic parts shall not contain PBB (Polybrominated biphenyls) or PBDE (Polybrominated diphenyl ethers) flame retardants. Plastic parts shall not contain chloroparaffin flame retardants with chain length 10-13 carbon atoms and chlorine content > 50% by weight (CAS no. 85535-84-8 – chemical name Chloroalkanes C10-13). Certificate that the requirement is fulfilled is needed.

- ***Flame retardants in plastic parts heavier than 25 grams*** **–** Plastic parts heavier than 25 grams shall not contain flame retardant substances or preparations that are assigned for any of the risk phrases as defined in Directive 67/548/EEC as last amended by Commission Directive 98/98/EC [20]: R45 (may cause cancer), R46 (may cause heritable genetic damage), R60 (may impair fertility), R61 (may cause harm to the unborn child). Furthermore, flame retardants shall not be named in Annex 1 to Directive 67/548/EEC or its subsequent amendments regarding the classification, packaging and labelling of dangerous substances. Certificate that the requirement is fulfilled and a specification of flame retardants used including name and CAS no. (unique numerical identifiers assigned by the Chemical Abstract Service to every chemical described in the open scientific literature) is required.

- ***Declaration of refrigerant/foaming agent*** **–** The type of refrigerant and foaming agent used for the insulation shall be indicated on the appliance, near to or on the rating plate, to facilitate possible future recovery, and confirmed by the certificate.

- ***Antibacterial properties*** **–** Biocides that are defined in the Biocidal Product Directive (Directive 98/8/EC [21]) and other chemicals and additives that create an antibacterial surface[1], in or on the product, are prohibited from use. Declaration from the manufacturer/supplier that the requirement is fulfilled is necessary.

- ***Nanomaterials*** **–** Nanomaterials and particles[2] (such as nano-metals, nano-minerals, pure nano-carbon compounds and/or nano-fluorine compounds) must not actively be

[1] An antibacterial chemical limits or prevents the growth of micro organisms such as bacteria, fungi and protozoa (single-cell organisms).

[2] Nanoparticles are defined as microscopic particles that in at least one dimension are smaller than 100 nm. Nano-metals, for example, include nano-silver, nano-gold and nano-copper. Nano-minerals include titanium oxide, silicon and zinc oxide in nano form.

added to the product's surface unless there is sufficient documentation demonstrating that the material does not constitute a health or environmental hazard. Declaration from the manufacturer/supplier that the requirement is fulfilled is necessary.

➢ ***NOISE***

- **Limit noise emissions**[3] – Airborne noise from the appliance, counted as sound power, shall not exceed 40 dB(A). The measurement of the noise level and the information relating to noise shall be provided in accordance with Council Directive 86/594/EEC [22], using EN 28960 standard [23]. Report containing results of noise measurements and a certificate that the requirement is fulfilled is required.

- **Information to the consumer (noise level)** – Information about the noise level of the appliance shall be provided in a way clearly visible to the consumer[4]. This shall be done by the incorporation of this information in the energy label for refrigerators. Certificate that the requirement is fulfilled is needed.

➢ ***EFFICIENCY/PERFORMANCE***

- ***Life time extension*** – The availability of compatible replacement parts and service shall be guaranteed for 10 years from the time that production ceases and confirmed by the certificate.

- ***User instructions (manual)*** – The appliance shall be sold with an instruction manual, which provides advice on the correct environmental use. The cover page or first page shall bear the following text: "Information on how to minimize environmental impacts is given in this manual." Recommendations for optimal use of energy in the operation of the appliance shall also be provided in the manual.

➢ ***PACKAGING***

- ***Separation of materials*** – All packaging components shall be easily separable by hand into individual materials to facilitate recycling. Description of the packaging is required.

- ***Cardboard*** – Where used, cardboard packaging shall consist of at least 80% recycled material. Description of the packaging is required.

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[3] This requirement does not apply to chest freezers indicated as category 9: "household food freezers, chest" in Annex IV of Commission Directive 94/2/EC [24].

[4] All appliances have a new energy label which indicates a noise level – a new mandatory parameter.

CRITERIA SELECTION FOR THE AHP-HIPRE ANALYSIS

Based on the "Nordic Swan" criteria and on the fact that for a customer the environmental performance criteria are only part from the whole set of criteria taken into account, the whole hierarchy of consumers criteria was designed.

The final goal of the project is to select the best refrigerator. The best refrigerator is one which meets the criteria of sustainable development, understood as a friendly for the environment, user friendly, and economical in use.

The environmental impact was measured by three subcriteria: impact of the refrigerator measured by its construction properties, impact of the used refrigerant and the impact of the used packaging. The construction criteria are all taken from the "Nordic Swan" ecolabeling procedure. The environmental impact of the refrigerant in the Nordic Swan program is measured by its impact on the ozone layer (ODP) and on the climate change. The impact on the climate is measured by the refrigerant's Global Warming Potential index (GWP).

GWP is not the only index which measures the impact on the global climate. This impact can be assessed also by less popular, but more integrating index called Total Equivalent Warming Impact (TEWI). TEWI, like GWP, measures the impact of the refrigerant when, at the end of its use, it is released into atmosphere, but additionally it estimates the impact on the global climate of the installation during its regular operation. TEWI is calculated using the following formula:

$$TEWI = GWP * L * n + GWP * m * (1 - \alpha) + n * E * \beta$$

where:

Direct impact on global warming (leakage, losses during recovery):	**Indirect impact on global warming (energy consumption):**
L – refrigerants leakage [kg/yr]	E – energy consumption [kWh/yr]
n – life time of the installation [years]	β – CO_2 emissions during energy production [$kgCO_2/kWh$]
m – mass of refrigerant in installation [kg] α – refrigerant's recovery rate [%]	

Knowing that TEWI better estimates the refrigerant's impact on the atmosphere the authors decided to use the GWP because the indirect impact on the global climate is already measured by the higher running cost. Using TEWI, instead of GWP, will result in calculating this impact for the second time. Using GWP instead of TEWI to estimate the direct impact of the refrigerant is also justified with the assumption that all three refrigerators use the same amount of refrigerants and the recovery system guarantees the same efficiency in all three cases. The current system of refrigerant's recovery makes this assumption justified.

The environmental impact of the refrigerator is measured by eight criteria developed by the Nordic Swan ecolabeling program and the economic performance is measured by two criteria: price and the running cost. There are different parameters measuring the economic performance of the investment. One of the most popular one is the net present value (NPV). NPV aggregates the investment and running costs, but often these two costs are covered by different entities. Sometimes running cost and investment cost are also of different importance for the buyer, because high investment cost occurs simultaneously with other costs when the investor is naturally short of money. For those reasons, instead of using only NPV as an indicator of economic performance, it was decided to introduce simultaneously two economic parameters (running cost and price)

It was decided, that additionally to environmental and economic criteria it is also important if the refrigerator is accepted by the user. This depends if the refrigerator is reliable and user friendly. To measure how reliable the product is it was decided to use the Nordic Swan criteria (guarantee period, manual, life time extension) plus brand. To measure two groups of criteria are also important: economical performance, and consumer subjective preferences. The final hierarchy of criteria presents Figure 2.

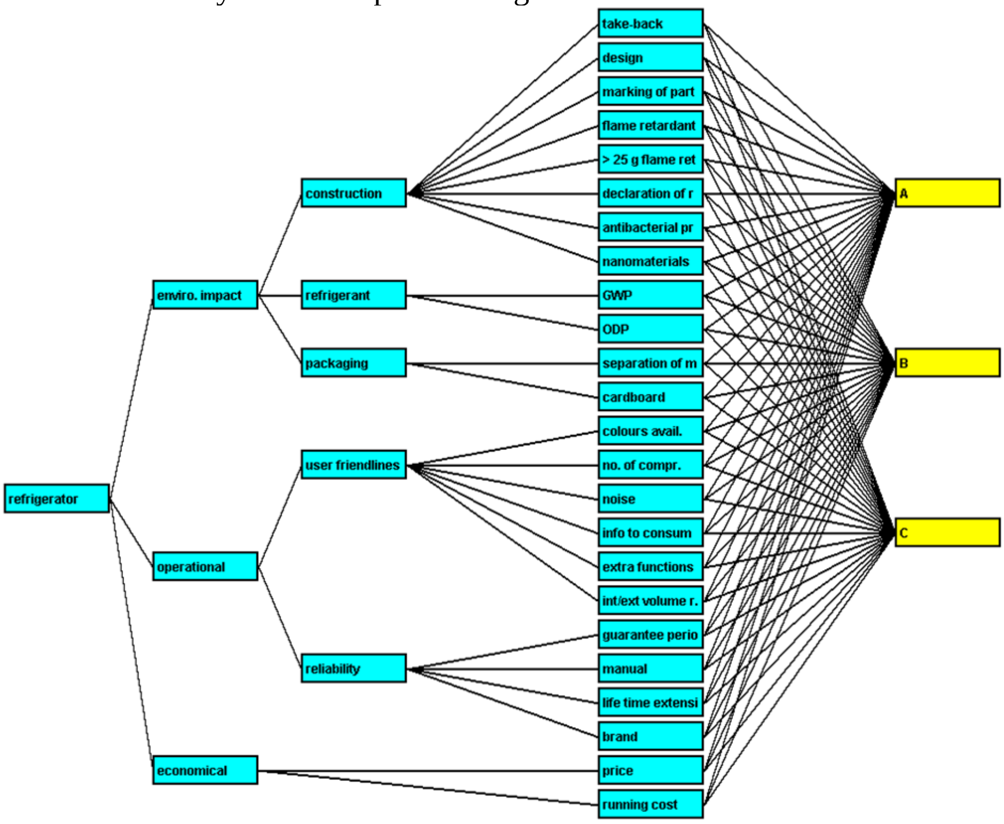

Figure 2 Objective hierarchy

The purchasing decision is also based on the subjective impression the refrigerator makes on the buyer. For this reason the following criteria are introduced into criteria evaluation hierarchy: user friendliness, internal/external volume, external functions, number of compressors, colors available. Criterion “internal/external volume ratio” measures efficient use of the space in the kitchen – parameter particularly important in small apartments.

Criterion „extra functions” measures how useful are the additional function of the refrigerator. The refrigerators can have a fancy displays showing temperature, but they can also have ice makers and many other advanced options. The criterion „colors available” measures the probability if the customer is going to buy a refrigerator in color he/she wants.

Criterion „number of compressors” measures the flexibility of refrigerator’s control. If the refrigerator has two independent compressors it makes possible to independently adjust the temperature in refrigerator and in freezer. It even gives an option to switch off one of the chambers.

DESCRIPTION OF THE SELECTED REFRIGERATORS

Three real refrigerators were selected for the analysis. For the purpose of the analysis there are labeled A, B, and C. Among many types of refrigerators the analysis focused on two chamber, refrigerator units with energy efficiency A++ or higher. The decision to focus on this highly efficient units results in elimination of “energy savings” from the hierarchy of criteria as a redundant one. This elimination is also justified by the fact that, the energy savings is measured by the running cost which is proportional to the energy consumption.

The information about the refrigerators were collected from the producers’ representatives. Data used in the analysis presents Table 1.

Table 1 Characteristics of the selected refrigerators

	Refrigerator					
Criteria	**C**	**A**	**B**	**Min rating**	**Max rating**	**Unit**
manual (user instructions)	1	1	1	0	1	Yes/No (1/0)
guarantee period	24	24	24	12	36	months
price	2745	2843	1448	1000	3000	PLN
running cost	98,28	110,88	154,35	90	200	PLN/yr
design	1	1	1	0	1	Yes/No (1/0)
flame retardants in plastic parts	0	0	0	0	1	Yes/No (1/0)
flame retardants in plastic parts > 25 g	0	0	0	0	1	Yes/No (1/0)
antibacterial properties	0	0	1	0	1	Yes/No (1/0)
nanomaterials	0	0	0	0	1	Yes/No (1/0)
declaration of refrigerant/foaming agent	0	0	0	0	1	Yes/No (1/0)
life time extension	1	1	1	0	1	Yes/No (1/0)
cardboard	0	0	1	0	1	Yes/No (1/0)
extra functions	12	12	4	0	20	number
internal/external volume ratio	0,429	0,446	0,465	0,429	0,465	-
limit noise emissions	38	38	39	20	40	dB(A)
information to the consumer (noise level)	1	1	1	0	1	Yes/No (1/0)
marking of plastic parts	0	0	0	0	1	Yes/No (1/0)
separation of materiale	0	0	0	0	1	Yes/No (1/0)
brand	4	4	3	1	4	-
ODP	0	0	0	0	1	kg CFC-11 eq./kg
number of compressors	1	1	1	1	2	number
colours available	0	0	0	0	1	Yes/No (1/0)
take-back and recycling	0	0	0	0	1	Yes/No (1/0)
GWP	3	3	3	1	3	kg CO_2 eq/kg

For the final result of the analysis the acceptable range for each parameter is also important. Generally it was assumed to be between the maximum and minimum value of the parameter, but sometimes the authors made arbitrary decision. For example, it was assumed that the minimum acceptable price for the refrigerator of this quality is 1000 PLN (240 Euro) and the maximum price is 3000 PLN (720 Euro).

COMPARATIVE ANALYSIS OF THE REFRIGERATORS – APPLICATION OF AHP-HIPRE FOR THE REFRIGERATOR'S SELECTION

The available in the Internet, free AHP software was used for the analysis [3]. The software is provided by the University of Helsinki and is called AHP-HIPRE. The second step of the AHP process is assigning the weights to each criterion by comparing criteria in pairs. The comparison scale is from 1, if they are of equal importance, to 9 for a strong preference. The authors conducted the pair wise comparison of all criteria and obtained the final set of weights for the criteria. Authors estimated maximum and minimum accepted value for each criterion and defined if the value of the criterion should seek maximum or minimum value for the best solution.

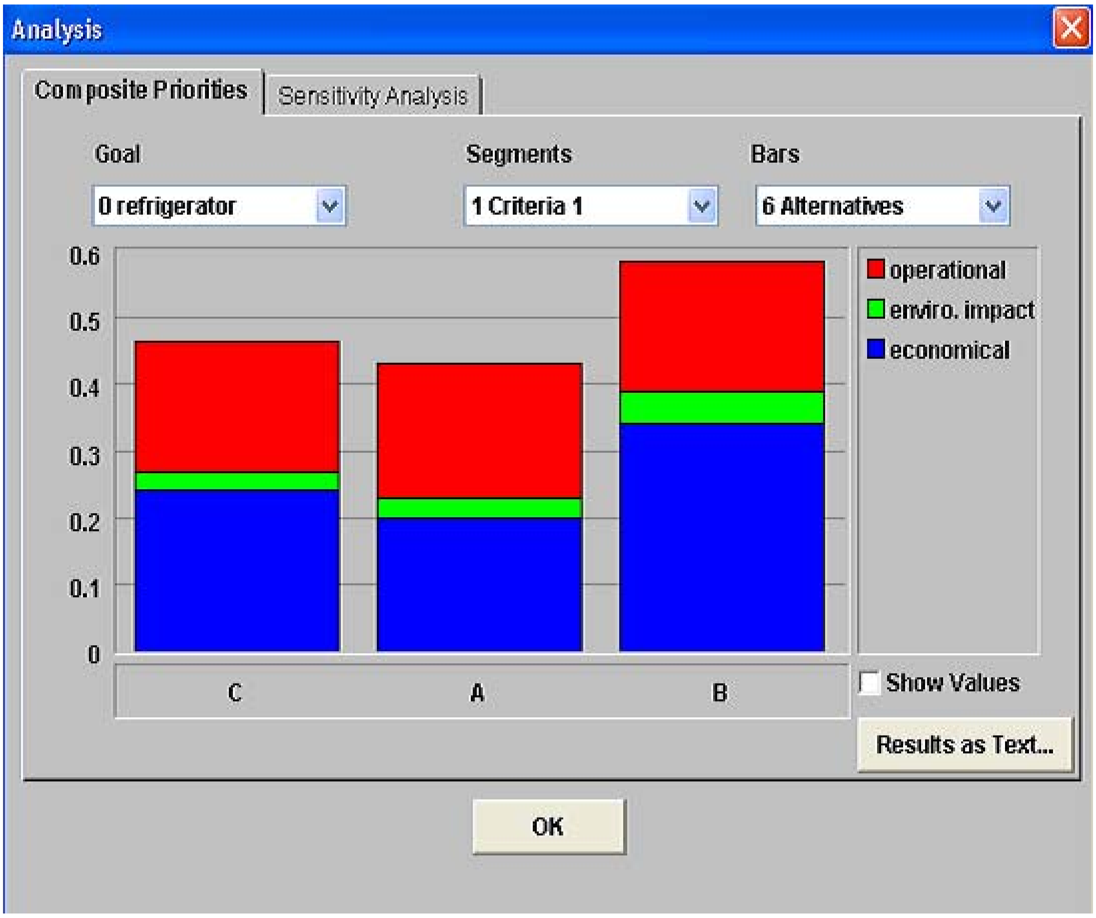

Figure 3 AHP scores for the refrigerator selection problem

Figure 3 presents the results of the AHP analysis. The size of the bar shows the total performance of each model. In the analyzed case refrigerator B was found to be the best one with the score 0,586. Refrigerator C was the second choice with the score 0,464 and refrigerator A was the last choice with the score 0,432. In other words, refrigerator B was significantly better choice than the two others which were found very comparable.

When looking more carefully at the structure of obtained result it turns out that refrigerator B is better that refrigerators A and C thanks to its better economical performance. Economical performance is measured by two criteria (see Figure 4). More detail analysis shows that refrigerator B is evaluated highly because of its price, and poorly because of its high running costs All in all, low price fully compensates high running costs giving the highest total score for the economical performance.

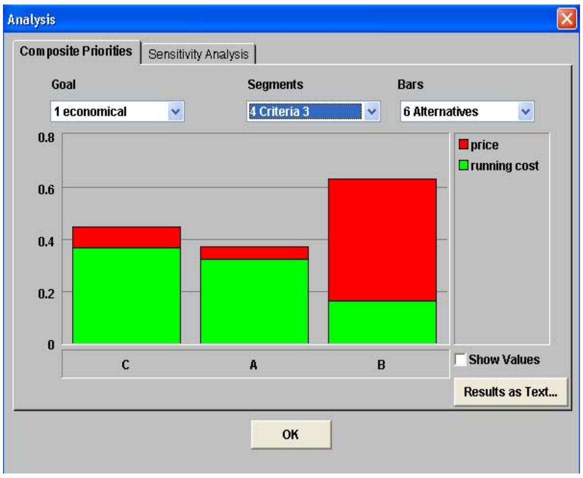

Figure 4 Economical performance

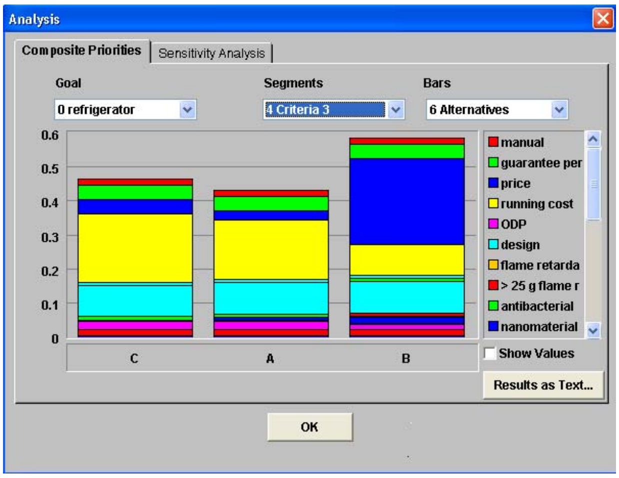

Figure 5 The detailed breakdown of the obtained results

Figure 5 shows the detailed breakdown of the obtained results. It turns out that only price and running costs make the difference in final evaluation while all the other criteria give very comparable results and do not have significant impact on the final score.

Another problem is how reliable are the result and how they will change if changing the assumptions. This problem is analyzed by the sensitivity analysis.

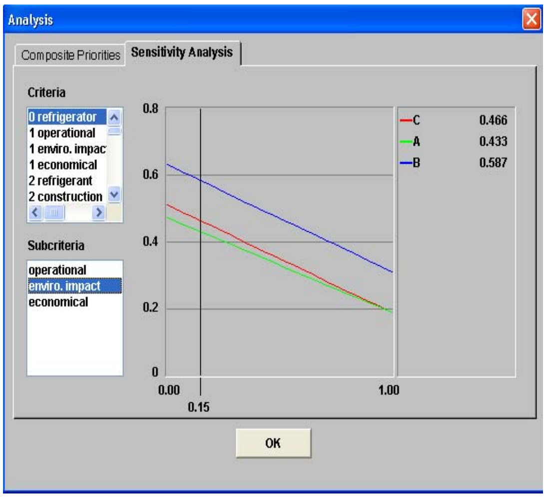

Figure 6 The sensitivity analysis – the environmental criterion

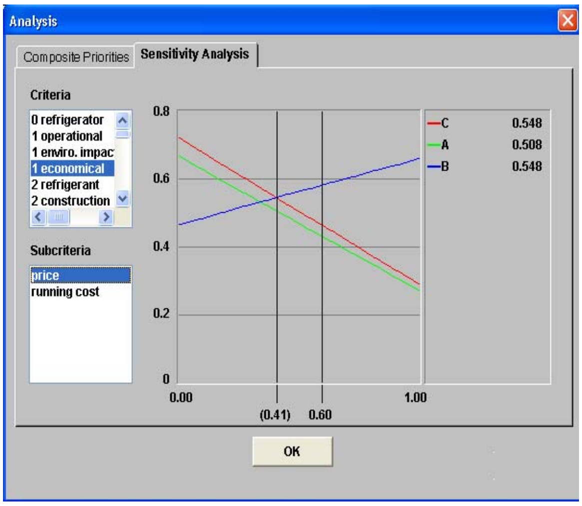

Figure 7 The sensitivity analysis – the economical criterion

Generally, the sensitivity analysis shows that the refrigerator B remains the best solution no matter what is the weight assigned to the environmental criterion.(Fig 6)

The very similar result gives the change of weight assigned to the economical ratio (see Figure 7). The weight has to drop from the present 0,6 to 0,41 to make the refrigerator C the best choice. Changing the weights change the final score of all refrigerators, but not the ranking list. In case of operational criterion changing the final ranking of the solutions is possible, the weight of this criterion has to increase from the present 0,31 to 0,91. Such significant change is rather unlikely.

CONCLUSIONS

Advanced comparison of different equipment or technologies requires the use of some kind of multi criteria evaluation method. Presented AHP method shows its potential in such analysis. This is a flexible method which can be used for the whole spectrum of problems. The free software helps with the implementation.

Developing the criteria for the equipment analysis is a challenge, because the customers often do not know which parameter is really important. Implementing the criteria developed by professionals during the products' environmental evaluation summarized in the ecolabeling process can be of help. The presented example of refrigerators' selection showed how such an evaluation method works in practice, but also that the products from the same class are very comparable and the economical parameters are of the highest importance.

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