Comparative Analysis of AHP and DEX Decision Making Methods

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Abstract

Two multiattribute decision making methods, AHP and DEX, are compared with respect to decision knowledge management. Both methods rely on hierarchical decomposition of criteria. AHP (Analytic Hierarchy Process) is a quantitative method based on a matrix of relative importance of criteria and a matrix of relative comparison of options. DEX (Decision EXpert) is a qualitative method whose models use variables with descriptive values, and utility functions that are expressed by decision rules. The knowledge management is discussed in the frame of organizational effectiveness, comprehensibility and explanation of results. The comparison is carried out on a real-life example of environmental projects evaluation.

Introduction

In multiattribute decision making, preferential modeling is based on knowledge about (1) attributes and their structure, (2) alternatives, and (3) utilities (Keeney, Raiffa 1976; Chankong, Haimes 1983; Triantaphyllou 2000). The decision model is aimed at expressing all decision-relevant features of alternatives according to the decision maker's objectives. Knowledge about alternatives represents the decision maker's view on alternatives; the decision maker should know them sufficiently well to describe or measure them along attributes. Knowledge about utilities can be treated in two steps. The first step is to establish a dependence between attribute's real values (money, size, age, etc., measured on alternatives) and their utilities as a reflection of decision maker's preferential opinion. The second step is the aggregation of these partial utilities into the final overall utility value (Rajkovič et al 1988; Dyer et al 1992; Buede, Maxwell 1995).

A number of methods have been developed to support the decision knowledge management (Humphreys, Wisudha 1987; Nagel 1992; Triantaphyllou 2000). One of the well known approaches is hierarchical decomposition in which the decision problem is decomposed into smaller and less complex subproblems (Bohanec 2003). The result of decomposition is a hierarchical decision model. Such decomposition contributes to a better fit between decision models and human understanding. By this, the decision makers' cognitive processes are supported by decision knowledge which can be easily understood, and can be easily updated and actively used by all participants in the decision making process (Bohanec, Rajkovič 1993; Goodwin, Wright 1998).

In this paper we compare two different hierarchical decision approaches: AHP and DEX. AHP (Analytic Hierarchy Process; Saaty 1993) is a well known method for a numerical evaluation and analysis of options. A distinguishing characteristic of AHP is a method to obtain the elements of decision models that is based on a pairwise comparison of criteria and options. For the purpose of this paper, we used AHP as implemented in the program Expert Choice[1]. The second approach, DEX (Bohanec et al 1992), uses qualitative decision models. Each variable in the model can take only symbolic values, which are usually expressed with words such as *good* or *unacceptable*. The aggregation of partial evaluations into the overall evaluation is carried out by decision rules. This methodology is supported by an expert system shell DEX (Decision EXpert; Bohanec, Rajkovič 1990) that was successfully used for supporting several different decision processes (Bohanec et al 2000a, 2000b, 2003).

The goal of this paper is to analyze the strengths and weaknesses of both approaches and to propose a complementary usage of them for effective decision knowledge management. The comparison is explained on a real-life example of environmental projects evaluation. Both methodologies and the corresponding programs are presented in parallel following the major steps in decision model development (Bohanec 2003): (1) hierarchical decomposition of criteria, (2) aggregation, (3) assessment of options and (4) analysis of results. The paper is concluded by a critical analysis of the approaches and recommendations for their practical application.

Decision Problem: Project Evaluation

To compare and evaluate AHP and DEX, we applied them in a real-world problem of evaluating possible projects in an environmental consulting company OIKOS Inc. The problem was complex enough to enable a sound comparison of the methodologies, but also simple enough for a feasible development of two decision models.

The work in OIKOS is organized in projects. Usually, there are more ideas for future projects than the company has available human resources and finance. Therefore, the management has to make strategic

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[1] Expert Choice is a product of Expert Choice, Inc., Pittsburgh, PA 15213, USA (http://www.expertchoice.com/).

decisions which projects to undertake. The company decided to develop a decision model to help the management making such decisions, and also to present the important aspects of projects to all the employees.

The model for project evaluation consists of three groups of criteria: gains, market and implementation. Each of them is further decomposed so that the corresponding parameters can be simply assessed or measured. The hierarchy of criteria for the evaluation of projects is shown in Figure 1.

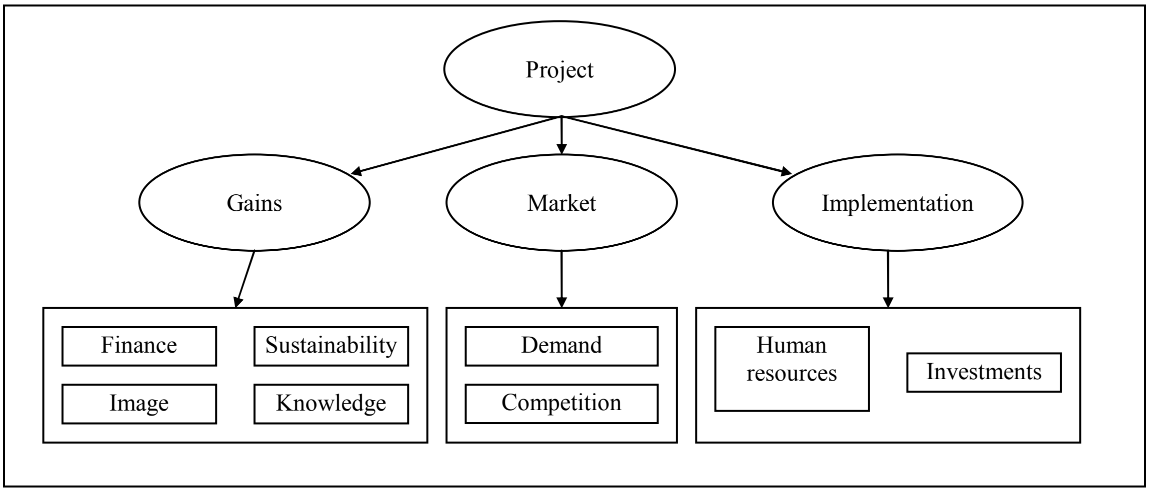

Figure 1. Hierarchy of criteria in for project evaluation

Gains of the project can be fourfold. In addition to financial gains, there are gains that reflect in the improved knowledge of employees, or improved reputation (image) of the company. The sustainability of the project is also important, since consulting companies seldom have many long-term contracts, which are desired because of the stability they bring.

Market describes the ability of the company to actually get the contract for the project. This primarily depends on demand for such projects by potential clients and the competition of other companies in the market. *Market* has the same meaning as *market attractiveness* in a popular portfolio analysis methodology (Neubauer 1989).

Implementation is the company's ability to accomplish the project successfully in terms of the quality of outcomes, time frame, achieved goals, and achieved expected gains. We assess this ability by the available human resources (employees or other contractors) and necessary investments. The project which requires large investments (either direct expenses or opportunity costs of employee time) is not preferred. To be accepted, it has to be evaluated much better by other criteria than the project which can start without much investment. *Implementation* can be viewed as *competitiveness* in portfolio analysis.

Seven projects were evaluated in our research (Table 1). These projects were actually the representatives of primary project types that the company can perform. Some of the chosen projects were already in progress and the management was deciding whether to continue with them or not, while others were only ideas at the time of evaluation.

Table 1. List of evaluated projects

LEAP_D	Local Environmental Action Plans (LEAP) in Slovenian municipalities
LEAP_I	International LEAP projects
EIA	Environmental Impact Assessments
MGMTPL	Management plans for areas of preserved nature
PACKAGING	Packaging of environmental and development projects for international funding
SWM	Solid Waste Management programs
WWTP	Planning and implementation of small waste water treatment plants

Development of Decision Model

Hierarchy of Criteria

Both AHP and DEX use the technique of hierarchical decomposition of complex decision problems. The hierarchy from Figure 1 was in both cases directly used in software for evaluation.

Aggregation

AHP

The aggregation in AHP is based on a numerical comparison of criteria for describing their importance. At each level, the criteria are compared one to another in a comparison matrix. The elements of matrix are numbers from 1 to 9, or 1/9 to 1. When the criterion in row *i* is more important than the criterion in column *j*, the corresponding element of the comparison matrix is set to a value from 1 to 9. The meaning of these values is described in Table 2. When the criterion *i* is less important than *j*, the corresponding matrix element is set to the reciprocal of this value. Consequently, the diagonal elements of comparison matrix are all equal to 1, and the matrix is reciprocal symmetric.

Table 2. The meaning of elements of comparison matrix

1	criteria *i* and *j* are **equally** important
3	criterion *i* is **moderately** more important than *j*
5	criterion *i* is **strongly** more important than *j*
7	criterion *i* is **very strongly** more important than *j*
9	criterion *i* is **extremely** more important than *j*

An example in Figure 2 shows a comparison matrix for the criterion *Gains* in the developed model.

$$
\begin{array}{r c}
 & \begin{array}{cccc} \text{Fin} & \text{Sust} & \text{Im} & \text{Kn} \end{array} \\
\begin{array}{r} \text{Finance} \\ \text{Sustainability} \\ \text{Image} \\ \text{Knowledge} \end{array} &
\begin{bmatrix} 1 & 5 & 7 & 8 \\ 1/5 & 1 & 3 & 5 \\ 1/7 & 1/3 & 1 & 2 \\ 1/8 & 1/5 & 1/2 & 1 \end{bmatrix}
\end{array}
\Rightarrow
\begin{bmatrix} 0.655 \\ 0.207 \\ 0.085 \\ 0.053 \end{bmatrix}
$$

Figure 2. A comparison matrix and calculated weights for the criterion *Gains*

When the comparison matrix has been defined, the weights of criteria are calculated as normalized eigenvector of comparison matrix.

The consistency of the matrix can be assessed through *consistency index*. This index indicates the extent of errors in comparisons. Inconsistency occurs, for example, when option A is strongly more important than B, B is strongly more important than C, but A is only moderately more important than C. Empirically, the index higher than 0.1 indicates inconsistency.

The time spent for setting up the comparison matrices for the problem was short: about fifteen minutes in total. The software package facilitated various methods for pairwise comparison of criteria: verbal (i.e., using the terms from Table 2, such as *equally* or *moderately*), numerically, and graphically (using slidebars).

<u>DEX</u>

In contrast with AHP, DEX uses qualitative criteria. Each criterion in the hierarchy (Figure 1) is defined as a discrete variable that can take its values from a set of symbols. These symbols need to be defined for each criterion separately by the developer of the model and typically consist of words such as *good*, *excellent*, or *unacceptable*. Value sets are small and in most cases consist of two to five words. For the OIKOS case, the value sets were defined as shown in Table 3. Note that all the value sets were ordered from bad to good with respect to the acceptance of the project. In Table 3, particularly bad and good values are printed in bold and italics, respectively. Although the ordering of value sets is not required in DEX, it is preferred as it improves two of the following stages: it simplifies the definition of decision rules and facilitates selective explanation.

Table 3. Definition of criteria's value sets in the DEX evaluation model

Criterion	<u>Value set</u>
Project	**Reject**, Poor, Average, *Good*, *Very good*
Gains	**High loss**, **Loss**, Breakeven, *Moderate profit*, *High profit*
Finance	**Loss**, Breakeven, *<$40.000/a*, *40-$100.000/a*, *>$100.000/a*
Sustainability	One time, *Few years*, *Long-term*
Image	**Bad**, No impact, *Good*
Knowledge	Nothing learned, *Something*, *A lot*
Market	**No market**, **Poor**, Average, *Good, Very good*
Demand	**No demand**, Poor, Average, *Good*, *Very good*
Competition	**Monopoly**, **Very strong**, Strong, *Average*, *Poor*, *Negligent*
Implementation	**Very difficult**, **Difficult**, Possible, *Easy*
Human resources	**Not available**, Some, *Available*
Investments	**Large**, Small, *None*

In DEX, the use of qualitative criteria requires quite a different approach to aggregation than AHP's. Instead of weights, the aggregation is carried out by *decision rules*. These are simple "if-then" rules defined by the designer, with which the aggregation function is expressed point-by-point for all possible combinations of attribute values. They are usually represented in a tabular form. An example in Table 4 shows a set of nine decision rules for the aggregation of criteria Human resources and Investments into Implementation. This is the smallest table in the OIKOS' model. The largest table, on the other hand, consists of 135 rules that aggregate the four criteria Finance, Sustainability, Image and Knowledge into Gains. The remaining two tables, Market and Project, contain 30 and 100 rules, respectively.

Table 4. Decision rules for the aggregation of Implementation

Rule	Human resources	Investments	Implementation
1	Not available	Large	Very difficult
2	Some	Large	Difficult
3	Available	Large	Difficult
4	Not available	Small	Very difficult
5	Some	Small	Difficult
6	Available	Small	Easy
7	Not available	None	Very difficult
8	Some	None	Possible
9	Available	None	Easy

The definition of decision rules with DEX proceeds as follows. First, DEX prepares a table that consists of all the possible combinations of values of input criteria, while the rightmost column, which corresponds to the output criterion (Implementation in Table 4), is left undefined. The designer then needs to fill-in only the values in the rightmost column. This process is permanently monitored by DEX, providing two kinds of assistance:

- consistency checking of newly defined rules, and
- determining the lower and upper bounds of currently undefined rules.

Consistency checking is performed by DEX whenever the user enters a new rule. As the criteria are usually preferentially ordered, the aggregation function must increase or at least remain constant with increasing values of its arguments. Otherwise, an option with all values better or equal than some other option would unfairly be evaluated as a worse option. In other words, the aggregation function must be monotone. This is verified by DEX as illustrated by an example in Table 5. There, the user has just entered the value of the second rule. In comparison with the first rule, the value of Attribute 2 has increased from poor to good, while Attribute 1 remained constant. Since both attributes are preferentially ordered, the value of Result must not decrease, so the user's entry violates the requirement for consistency.

Table 5. Example of violation of consistency

Attribute 1	Attribute 2	Result	
good	poor	**good**	
good	good	poor	← VIOLATION !

Determining lower and upper bounds of currently undefined rules is a method aimed at reducing the number of values the user needs to define in order to completely define the table of rules. The method again relies on the preferential order of attributes' value sets. For all entries in the table that have not been explicitly defined by the user, DEX calculates their lower and upper bounds from other already defined rules so that the assigned interval is the largest one that preserves the monotonicity of the aggregation function. An example is shown in Table 6, in which the first and the third rule have already been defined. Although the value of the second rule has not been explicitly stated, it follows from the first rule that its lower bound is good, and from the last rule that its upper bound is excellent. Therefore, the possible range of values that can be assigned to the second rule is between good and excellent, inclusively. As the value excellent is the highest possible qualitative value of Attribute 2, the interval [good,excellent] is presented as '≥ good' in Table 6, meaning 'better that or equal to good'.

Table 6. Example of determining lower and upper bounds for a currently undefined rule

Attribute 1	Attribute 2	Result	
good	poor	**good**	
good	medium	≥ good	← not explicitly defined yet
good	good	**excellent**	

In order to present decision rules in a compact and comprehensible way, DEX can generalize a large number of rules into *complex rules*, where wildcards are used for individual attributes. For example, 135 rules for criterion *Gain* are represented by 33 complex rules; three of these are presented in Table 7.

Table 7. Example of complex rules in DEX. The asterisk '*' denotes any value.

Finance	**Sustainability**	**Image**	**Knowledge**	Gains
Loss	*	Bad	<= Something	High loss
<=Breakeven	*	Bad	Nothing learned	High loss
Loss	One_time	Bad	*	High loss

Despite all the assistance methods described above, the definition of decision rules in DEX takes considerably longer than creating comparison matrices in AHP. In our case, 100 rules had to be determined on a top level (evaluating projects by three criteria Gains, Market and Implementation), and additional 135, 30 and 9 rules on the second level of the hierarchy. Altogether we had to determine 274 rules. DEX's ability to recommend the values of currently undefined rules enabled us to fully determine the aggregation functions by explicitly defining only about 50% of rules. Nevertheless, this process still took about one hour.

Assessment of Options

AHP

The assessment of options in AHP is done by comparing all options on each criterion. Comparison matrices are prepared for a set of options for every criterion. Calculating normalized eigenvector yields the numerical assessment of every option for the corresponding criterion. These values are then multiplied by weights, which were obtained in the previous stage of model development, and the final numerical evaluation is calculated for every option. It is possible to compare overall values of options as well as options in individual nodes of the hierarchy. An example of comparison matrix for the criterion Demand is shown Figure 3. The overall results of evaluating seven projects are presented in Table 8.

$$
\begin{array}{c}
\\
LEAP\_D \\ LEAP\_I \\ EIA \\ Mgmtpl \\ Packagin \\ SWM \\ WWTP
\end{array}
\begin{array}{c}
\begin{array}{ccccccc} LD & LI & EIA & MP & PC & SWM & WW \end{array} \\
\begin{bmatrix}
1 & 3 & 1/5 & 3 & 1/5 & 7 & 1/3 \\
1/3 & 1 & 1/7 & 1 & 1/9 & 5 & 1/5 \\
5 & 7 & 1 & 7 & 2 & 9 & 5 \\
1/3 & 1 & 1/7 & 1 & 1/5 & 5 & 1 \\
5 & 9 & 1/2 & 5 & 1 & 8 & 3 \\
1/7 & 1/5 & 1/9 & 1/5 & 1/8 & 1 & 1/5 \\
3 & 5 & 1/5 & 1 & 1/3 & 5 & 1
\end{bmatrix}
\end{array}
\Rightarrow
\begin{bmatrix}
0.093 \\ 0.045 \\ 0.379 \\ 0.061 \\ 0.280 \\ 0.020 \\ 0.123
\end{bmatrix}
$$

Figure 3. A comparison matrix for comparing options on single criterion

Even for a relatively small number of options, the pairwise comparison of options for each criterion can be time consuming and stressful. To evaluate seven options in our simple model, we had to make 8 comparison matrices. In each matrix, we had to determine 21 elements, as a half of the matrix is reciprocal to the other part, and the diagonal is always 1. Making over 150 comparisons is not an easy task and evaluators tend to lose concentration over time. This stage took us about one hour.

Thus, the main disadvantage of the pairwise comparison approach is that the number of comparisons increases quadratically with the number of options. This effectively limits the number of options that can be feasibly evaluated. To alleviate this problem, Expert Choice provides an alternative method in which options are assessed through ranking. In this case, the bottom level of hierarchy are not the options, but ranks. After these ranks are evaluated, they are summed up to obtain the evaluation of options.

Table 8. Evaluating projects by AHP

Criterion	**Weight**	**EIA**	**PACK**	**MGMNT**	**WWTP**	**LEAP_D**	**LEAP_I**	**SWM**
Gains	0,537							
Finance	0,351	0,176	0,141	0,351	0,264	0,264	0,264	0,088
Sustainability	0,111	0,111	0,087	0,011	0,081	0,019	0,045	0,007
Image	0,046	0,003	0,029	0,010	0,012	0,007	0,046	0,003
Knowledge	0,028	0,002	0,022	0,007	0,015	0,005	0,028	0,002
Market	0,364							
Demand	0,319	0,319	0,235	0,051	0,104	0,078	0,038	0,017
Competition	0,046	0,016	0,044	0,046	0,003	0,044	0,008	0,005
Implementation	0,099							
Human resources	0,082	0,082	0,014	0,070	0,004	0,046	0,014	0,009
Investments	0,016	0,016	0,005	0,016	0,003	0,016	0,001	0,006
RESULTS		**0,213**	**0,169**	**0,165**	**0,143**	**0,140**	**0,130**	**0,040**

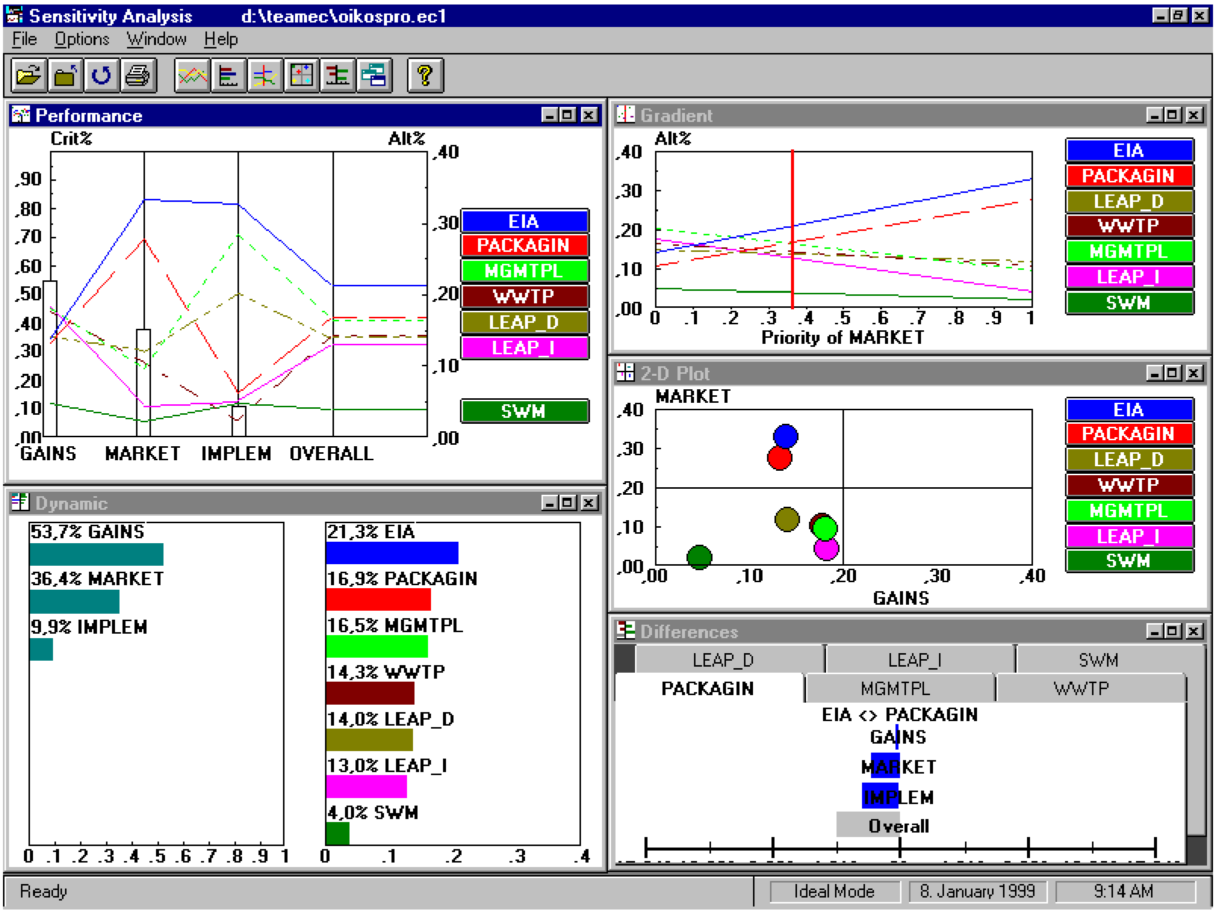

Figure 4. Sensitivity analysis in Expert Choice

Since options are evaluated numerically in AHP, they are generally different from each other. Even when ranking is applied, different options are distinct from each other. This is especially important when comparing similar options, what is often a case in real life.

Altering the model was possible by adjusting the importance of each criterion. Expert Choice implements a sensitivity analysis, where dependencies between the weights of criteria and the results of evaluation are presented graphically. Adjustments of the weights can be done graphically and the effects are seen immediately. In Expert Choice, five different views are provided for these purposes (Figure 4).

DEX

In DEX, options need to be described explicitly by determining the qualitative values of all the attributes. Options are independent of each other and their number is not limited. DEX allows attributes without values; in such case, the evaluation result in general is not a single value, but a range of values. It is often the case that an option can be evaluated with a single value, even if some attributes are missing. An example of evaluation report is given in Figure 5.

	LEAP_D	**LEAP_I**	**EIA**	**Managemnt**	**Packaging**	**Solid waste**	**WWTP**
Project	**Very good**	**Good**	**Very good**	**Very good**	**Very good**	**Reject**	**Average**
Gains	High profit	High profit	High profit	High profit	High profit	Moderate pr	High profit
Finance	40-$100.000	40-$100.000	40-$100.000	>$100.000/a	<$40.000/a	<$40.000/a	40-$100.000
Sustain	Few years	Long-term	Long-term	Few years	Long-term	Few years	Long-term
Image	Good	Good	No impact	Good	Good	No impact	Good
Knowledge	Something	A lot	Nothing lea	A lot	A lot	Something	A lot
Market	Good	Poor	Average	Good	Very good	No market	Average
Demand	Average	Average	Very good	Average	Very good	Poor	Very good
Compet	Negligent	Very strong	Very strong	Negligent	Negligent	Very strong	Very strong
Implement	Easy	Easy	Easy	Easy	Easy	Easy	Difficult
Human_res	Available	Available	Available	Available	Available	Available	Some
Invest	None	Small	None	None	Small	Small	Large

Figure 5. An example of evaluation report in DEX

An interesting feature of DEX is a report of particular advantages and disadvantages of an option, called *selective explanation*. DEX exposes subtrees in which an option was evaluated extremely well or extremely bad. Note that these extreme values have been determined at the time of model creation (see Table 3). An example of such a report is presented in Figure 6.

```
SELECTIVE EXPLANATION OF OPTION LEAP_I

ADVANTAGES                       DISADVANTAGES

Attribute      Value             Attribute      Value

+-GAINS          High profit     +-MARKET        Poor
¦ +-FINANCE      40-$100.000/a   ¦ +-COMPET      Very strong
¦ +-SUSTAIN      Long-term
¦ +-IMAGE        Good
¦ +-KNOWLEDGE    A lot

+-IMPLEMENT      Easy
  +-H_RES        Available
```

Figure 6. Presentation of advantages and disadvantages of options in DEX.

The results of evaluation were easy to understand, since we decided on the meaning of values at the time of modelling. Though several projects were evaluated with the same value, DEX was satisfactory answering the basic question of whether a project was worth undertaking or not.

VREDANA

Vredana (Šet et al 1995) is a supplementary computer program that extends DEX in the stage of option evaluation and analysis. Its main feature is combined qualitative and quantitative evaluation of options (Bohanec et al 1992). With this method, the options are not only evaluated qualitatively as in DEX, but also ranked numerically: the options that have been evaluated with the same qualitative value by DEX are ranked within that class value by Vredana. The quantitative evaluation procedure is derived automatically from decision rules.

Vredana evaluated the OIKOS' projects as shown in Figure 7. There were four projects they were evaluated qualitatively the same as *Very good* by DEX: LEAP_D, EIA, Management and Packaging. In contrast, Vredana's quantitative evaluation additionally ranked them within that qualitative class and revealed that Management was the best, and EIA the worst among the four projects.

Additionally, Vredana facilitates *what-if* analysis and provides various charts for the visualization of evaluation results. Figure 8 shows an example of 'radar' charts that are based on up to eight attributes selected by the user. They provide a graphical comparison of options and are particularly useful for indicating the strengths and weaknesses of options with respect to the selected attributes.

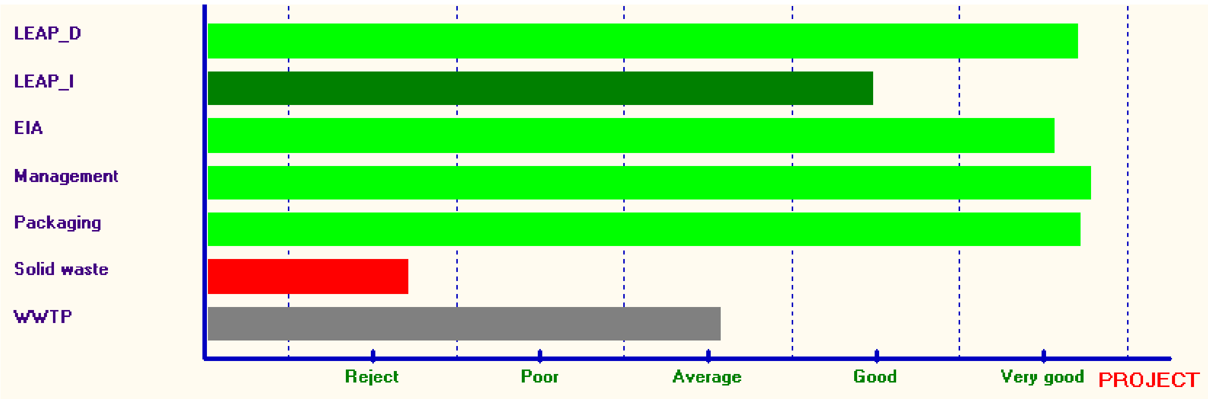

Figure 7: Quantitative evaluation of projects by Vredana

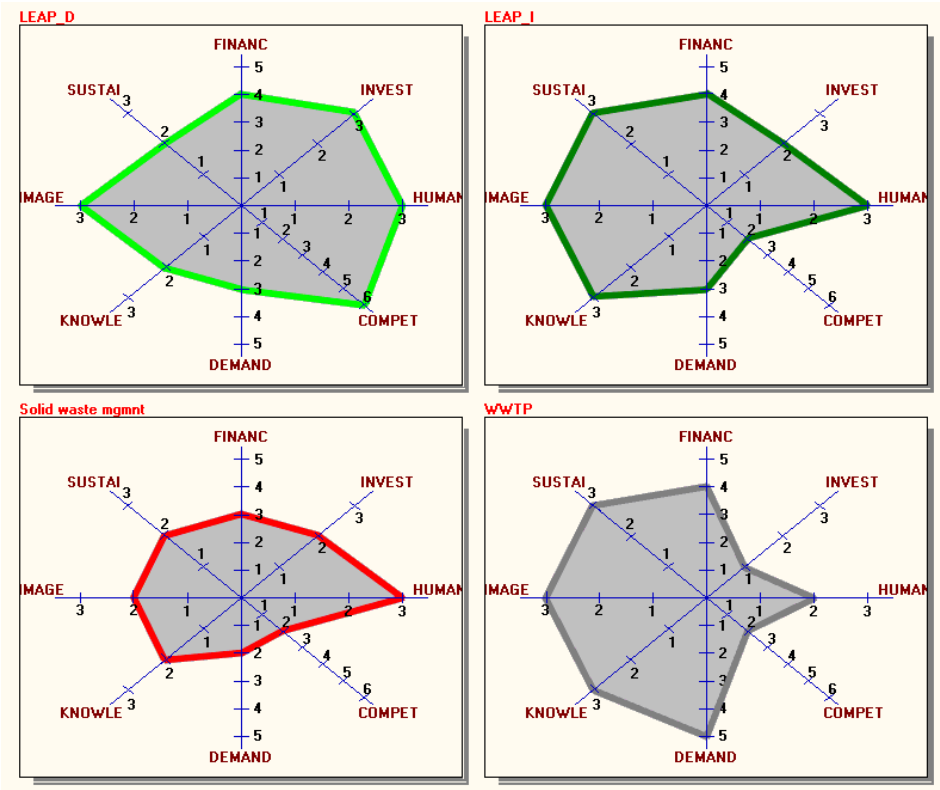

Figure 8: Visualization of evaluation results using 'radar' charts in Vredana

Results

Both AHP and DEX use hierarchical decomposition for developing decision models. The structure of criteria is identical, but the methodologies use different techniques for describing the options and aggregating the values of input criteria into the final result. AHP uses comparison matrices, while DEX is based on decision rules that aggregate qualitative values. Decision rules define the aggregation function point-by-point rather than analytically. Every decision rule represents a point in a multi-dimensional space of qualitative attributes.

The time needed to develop the model was considerably shorter with AHP than with DEX. In AHP we had to determine two matrices of dimensions 3 and 4 (only the upper triangle due to reciprocal symmetry), and make two comparisons of two criteria. The work was done in about fifteen minutes. With DEX, we had to determine 274 rules. Despite that 50% of rules were determined automatically by DEX, the work still demanded about one hour of concentrated work.

Description of options was on the other hand much simpler with DEX, where only the values of attributes had to be determined. In AHP, comparison matrices had to be determined for eight criteria: we had to set up eight matrices of dimension 7, what is 21 x 8 = 168 comparisons. For every option we add, more comparisons have to be made, as the number of comparisons increases quadratically with the number of options.

When comparing the results of evaluation, DEX gave very comprehensible symbolic results (project is very good, poor etc.), while AHP produced a numeric evaluation. DEX evaluated several projects with the same value, while AHP determined a unique value for every project. Results of evaluation with AHP were at first rather different from expectations, but with analysis of the model and adjustments, we could set up the model to evaluate the projects properly. DEX model was very close to the expected results: when analyzing the model, we only had to modify 4 rules to finalize the model. Altogether, developing the model, evaluating the options and fine-tuning took approximately the same time with both approaches.

With AHP, we were not confident whether the model was adequate. Although the model was reviewed before the evaluation of options, the evaluation results were considerably different to the expected ones, and the model had to be accordingly adjusted. Expert Choice provided plenty of ways to adjust the model to our needs, but here a question occurs: does not fitting the decision model to the expected results contradicts the primary aim of the whole procedure? If we already knew the results, do we need the model only to "justify" the decisions we have already made? With the use of AHP it is absolutely necessary to carefully examine every comparison when adjusting the model. Because the meaning of numbers is vague, evaluators shall critically evaluate the model and try to understand the meaning of numerical evaluations. They shall also find a compromise between blind trust in the developed model, possibly providing "strange" results, and fitting the model to give expected results, making the whole process obsolete, since we already knew the results.

Interpretation of the results of assessment in AHP was difficult. Options could be sorted by numerical evaluations, but we could not easily understand the results. For example, we were confident that EIA, which scored 0,213, was a good project and SWM with 0,040 was rather poor. But are the rest, which were evaluated from 0,130 to 0,169, all good or bad? Is the boundary between good and bad projects somewhere in between? It is not possible to answer these questions without a very careful analysis of the model and evaluation of a large number of options. In any case caution when developing the model and critical use of the results is very important, otherwise the results of an incomprehensible model can be misleading.

Since the first step in modeling with DEX is the determination of symbolic values, where the evaluators shall agree on their meaning, the rules in the model can be understood and checked at any point. The ability to generate *complex rules* enables the evaluators to verify the rules of the model without losing their track in the details. Once the model is built, it can only be altered by altering individual rules or by modifying value sets of individual criteria. In any case, the model remains stable (consistency is checked all the time) and the focus is always on the model, not on the expected results. The obtained results are very comprehensible, since the meaning of values of every criterion are known early in the model development process, i.e., immediately after the criterion value set has been defined.

The results of evaluation with both methodologies were almost the same, excluding the WWTP project. AHP evaluated it to be the fourth of seven projects, slightly better than LEAP_D project. DEX evaluated it only to be an *average* project, since it was difficult to implement due to the lack of human resources and high investments. The company management confirmed that implementation was a problem with this project and it could not be evaluated very high. Obviously, we did not sufficiently emphasize the weight of implementation in the AHP model, and this could not had been noticed without evaluating this specific project.

A drawback of the original DEX is low resolution of options: several different options can be evaluated by the same qualitative value. Therefore, a comparison of equally evaluated projects would be helpful. Vredana solves this problem to some extent, but for problems where tens or hundreds of options would be evaluated, an improved methodology would be needed.

Conclusion

Comparison of the methods on a case of project evaluation showed that DEX is more comprehensible method. AHP enabled better resolution of similar options, but the results were not clearly comprehensible. The results of DEX described exactly what was expected from the decision model: whether the proposed project is promising enough to be performed or not. For each project, DEX also highlighted its strengths and weaknesses, which is particularly important for successful project management.

Vredana is a tool which overcomes the drawback of basic DEX: low resolution of options. The analysis of options in Vredana showed small differences between options, which were evaluated as equal in DEX. In addition, it has implemented various graphical views, which enable even better understanding of the results of the analysis.

An interesting further work could be implementing a combination of DEX and AHP, where DEX would classify an option into a certain class, and AHP would be used for detailed evaluation within a certain class. The most important advantage of AHP is the ability to distinguish between similar options, for which creating comparison matrices is easier than for complex problems. Such two-step models usually give better results than models based on a single methodology (Manrai 1995).

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