The decision support system for supplementary activities on organic farms

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In this paper we present the decision support system for ranking food processing projects on organic farms. The system is based on simulation modeling and multi criteria decision analysis. The deterministic simulation system KARSIM EKO 1.0 (DSM) consists out of deterministic production simulation models that enable different types of costs calculations for organic production and on farm food processing in the framework of supplementary activities. Simulation models results were further evaluated using a qualitative multi-attribute modeling methodology, supported by the software tool DEX - i and quantitative analytical hierarchical process – AHP, supported by Expert Choice 2000TM software. The analysis showed that by using current model input parameter the combination of apple cider, apple vinegar and plum brandy (business alternative 1) results with the best multicriteria evaluation (EC = 0,413 and DEX – i evaluation = very good).

Key words: simulation modeling, KARSIM EKO 1.0, Expert Choice (AHP), DEX – i, organic farming, supplementary activities

INTRODUCTION

Since the beginning of the 1990s, organic farming has rapidly developed in almost all European countries. More than 5.4 million hectares were managed organically by almost 143 000 farms in the 25 countries of the European Union. This constituted 3.3 % of the agricultural area and 32 % of the farms in the EU (FiBL 2005). Organic farming is becoming more and more popular also among Slovene farmers. By the end of 2005 the number of farms practicing exclusively organic farming or taking up organic farming system amounted to more than 1 600 (or 1.85 % of all farms in Slovenia). The recent analysis showed that the average size of an Slovene organic farm is 13.4 ha. The data suggests that 4.7 % arable land in Slovenia is controlled by organic inspection body (MKGP 2006). In such a manner, the consumer preference for organic fruit food products on Slovene market is also high (Adamič 2000). In the practice the experience has shown that the organic farm products must be processed in to be sold more efficiently. The financial cost benefit analysis (CBA) is thus a necessity before a particular project on investment into food processing is undertaken. Some authors conducted studies where CBA methodology was used for decision making about ranking the food processing alternatives. Pažek (2003) analyzed 27 different food processing alternatives on Slovene organic farms using financial CBA. The only criterion in this study for the selection of the best investment alternative was the net present value (NPV). Recent works on decision support system in agriculture used a variety of methodological approaches. Rozman et al. (2002) combine simulation modeling and mathematical programming for selection of best apple orchard system. Turk and Rozman (2002) consider the capacity of simulation modeling and CBA for planning and decision making in fruit production. All before mentioned studies used financial criterion as prevailing criterion in the decision process.

Thus, cost-benefit analysis informs the decision making process, but it does not by itself make decisions. However, one should not automatically pursue the most financial efficient investment project, without weighing efficiency against the other important criteria that affect complete project desirability. Therefore in real world situation the decision on investment is rarely made on the basis of only financial criterion. In the case of food processing there are many other criteria that must be taken into consideration besides financial indicators such as NPV (Tiwari et al. 1999). Rogers and Bruen (1998) suggest the use of multi-criteria analysis to take into account different yet relevant criteria - even if these cannot be related to monetary outcomes - to be its main advantage. The most commonly applied approaches of MCDA are the analytical hierarchical process – AHP and the utility theory (Tiwari et al. 1999). Both before mentioned MCDA methods evaluate alternatives in empirical form. In the opposite, the approach based on the expert system for multi-attribute decision-making (DEX), uses qualitative variables and "if then" decision rules (Bohanec et al. 1995, Bohanec et al. 2000). In agriculture DEX – i was applied for the evaluation of some impacts by using genetically modified crops, with special emphasis on soil biology and ecology. The decision support system incorporates economic and ecological impacts of cropping systems (Bohanec et al. 2004). The same author presented a decision-support tool SMAC Advisor for the assessment of coexistence between genetically modified (GM) and conventional maize. The assessment is based on a DEX – i multi-attribute model (Bohanec et al. 2006). The MCDA for solution of some farm management decision problems is also described by other researcher (Hererro et al. 1999, Mazzeto and Bonera 2003), while the combination of

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simulation models and the multi-criteria method is discussed by Pažek et al. (2006), Rozman et al. (2006) and Klajić et al. (2000).

This paper presents application of simulation model KARSIM EKO 1.0 for cost analysis and investment planning on organic farms in combination with multi criteria decision models. The simulated alternatives are additionaly evaluated with multi attribute decision tools: Expert Choice decision support system (AHP) and DEX-i expert system.

METHODOLOGY

One of the goals of the research is to develop a computer-based decision support system for the assessment of financial, technological, ecological and market impact with special emphasis on supplementary activities on organic farms. Using the technologic-economic simulation modeling one can obtain information about the system itself and its responses to different model input parameters (Csaki 1985, Rozman 2004). The relationships between system elements (in this case input material, human labor) are expressed with a series of technological equations that are used for calculation (estimation) of input usage and outputs produced. For financial and technological analysis of the food processing on Slovene organic farms the computer simulation model KARSIM EKO 1.0 was developed (Pažek 2005). There are two basic sub-model: the sub-model of specific farm products and the sub-model of food processing into different final organic products. The developed model enables calculation of the most important economic parameters (break even price, coefficient of profitability, financial result,…) and financial indicators for the alternative evaluation (investment costs, Net Present Value, internal rate of return). The KARSIM EKO 1.0 output data represent some of the input parameter of analyzed farm business alternative in multi-criteria decision analysis. The decision simulation model (DSM) structure is shown in Figure 1.

The food processing investment alternatives are further evaluated with multi attribute decision model. A multi-attribute model is a hierarchical structure that represents the decomposition of the decision problem into sub-problems, which are smaller, less complex and possibly easier to solve than the complete model (Figure 2). The variants are decomposed in specific parameters (criterion, attribute, objective) and evaluated separately for each single parameter. The final variant evaluation is provided with the combine proceeding. The provided value presents the portfolio for selection of most suitable variant (solution) (Bohanec and Rajkovič 1995). For evaluation of simulated alternatives two methodological tools are applied: DEX - i expert System and AHP based Expert Choice (EC). DEX is an expert system shell for multi-attribute decision making that combines the "traditional" multi-attribute decision making with some elements of Expert Systems and Machine Learning. The distinguishing characteristic of DEX is its capability to deal with qualitative models. Instead of numerical variables, which typically constitute traditional quantitative models, DEX uses qualitative

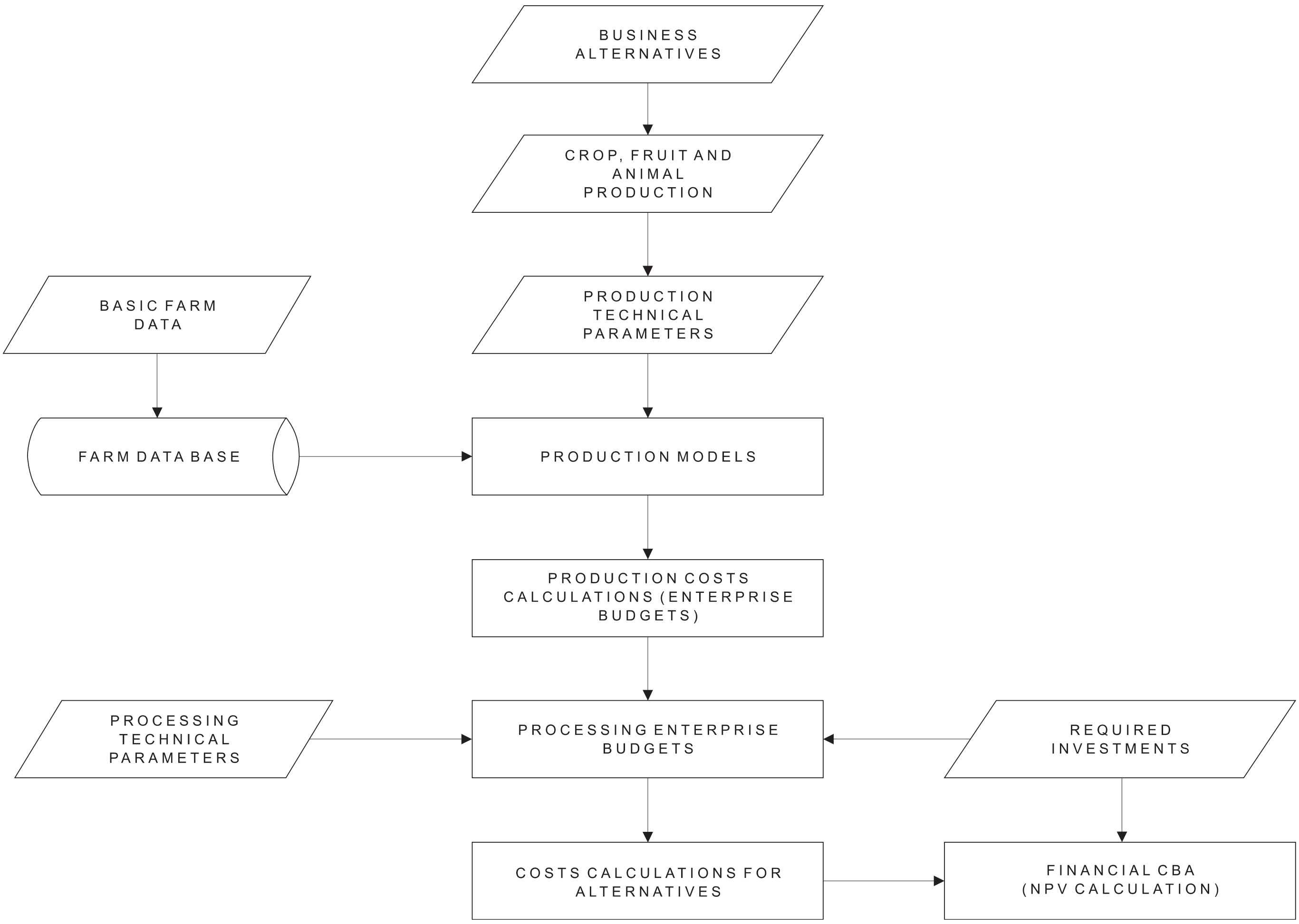

Fig. 1: The structure of deterministic simulation model (DSM) for cost calculations and planning on organic farms KARSIM EKO 1.0

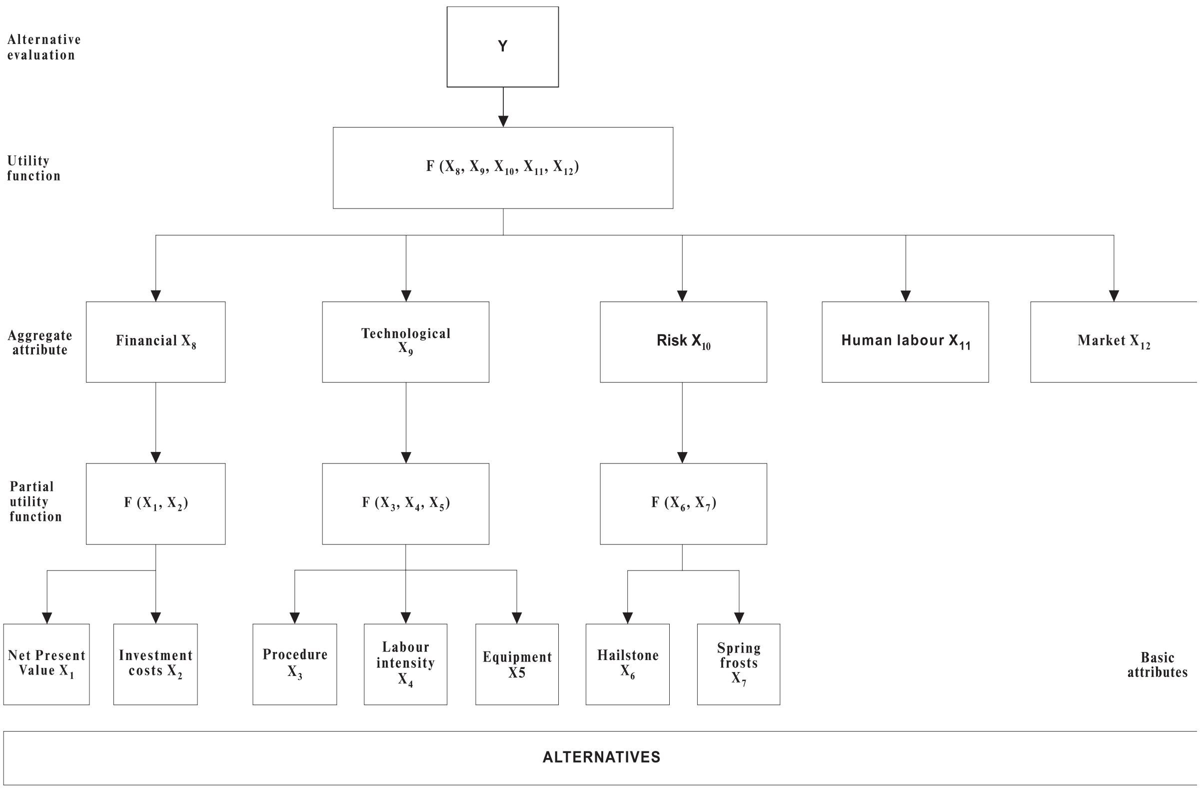

Fig. 2: The DEX-i decision model structure for the observed organic farm planning problem

variables; their values are usually represented by words rather than numbers, for example "low", "appropriate", "unacceptable", etc. Furthermore, to represent and evaluate utility functions, DEX uses if-then decision rules. In contrast, this is traditionally carried out in a numerical way, using weights or similar indicators of attributes' importance. An important additional feature of DEX is its capability to deal with inaccurate, uncertain or even missing data about options. Attributes are organized hierarchically and connected by utility functions that evaluate them with respect to their immediate descendants in the hierarchy. The utility functions evaluate each individual attribute with respect to their immediate descendants in the hierarchy. The decision rule can be, for instance: 'if the net present value is negative then the alternative is unacceptable' or 'if the labor usage in the investment project is low then the alternative is excellent'. In contrast, in DEX-i modeling this can also be carried out in a numerical way, using weights or similar indicators of the attributes' importance. Variables are connected by utility functions that aggregate partial sub-problems into the overall evaluation or classification of alternative (Bohanec et al. 1995, Bohanec and Rajkovič 1999, Bohanec and Zupan 2004). The DEX-i decision model is developed by defining:

- attributes (qualitative variables that represent decision sub-problems)
- tree of attributes (a hierarchical structure representing the decomposition of the decision problem)
- utility functions (rules that define the aggregation of attributes from bottom to the top of the tree of attributes) and
- alternative evaluation.

The numerical attributes for the DEX-i analysis were obtained by simulation using DSM (Table 1), while the non-numerical attributes were estimated based on different data

Table 1. Categorization table for numerically measured attributes

Investment costs (€)	Qualitative Values
0-1000	Very low
1001-3000	Low
3001-6000	Average
6001-9000	High
9001-12000	Extra high
> 12000	Extremely high
NPV (€)	
0-5000	Low
5001-10000	Average
10001-20000	High
> 20000	Extra high
Human labour (hours)	
0-50	Low
51-100	Average
101-200	High
> 200	Very high
Equipment requirements (equipment)	
0-2	Simple
3-4	Average
5-6	Demanding
> 6	Very demanding
Process (steps in processing technique)	
0-5	Simple
6-10	Average
11-15	Demanding
> 15	Very demanding

sources (i.e., past selling experiences and climatic characteristics). The following qualitative scales were used for non-numerical sub-attributes (Table 2).

After each attribute has been assigned with its scales (qualitative value), the utility functions (knowledge base) are defined. The utility function is conducted for each level in the hierarchy (partial utility function for aggregate attributes and overall utility function for the whole model except for the lowest level in the hierarchy). The decision rules are presented in complex form where the asterisk "*" means any value and >= equal or better (Table 3).

Finally, attribute values for each alternative are put into the DEX-i evaluation table and the analysis is ultimately conducted.

Table 2. Qualitative scales for non-numerical attributes

Market objective	poor; average; good; excellent
Spring frost frequency	high; average; low
Hailstone frequency	high; average; low

Another applied MCDA method is analytical hierarchical process (AHP) with application of decision support software Expert Choice 2000TM. The AHP is a decision-aided method which de-composes a complex multi-factor problem into a hierarchy. The AHP method determines the priorities of each alternative with the assigned weight for each alternative by analyzing the judgmental matrices using the advanced mathematical theory of eigenvalues and eigenvectors. It interprets the eigenvector associated with the largest eigenvalue as the priorities that indicate the importance of each alternative in accomplishing the objective. AHP combines both subjective and objective judgments in an integrated framework based on ratio scales from simple pair-wise comparisons. Saaty (1980) developed the following steps for applying the AHP:

Table 3. The decision rules for organic farm planning problem

Financial objective	Human labor intensity	Techno-logical objective	Market objective	Risk objective	Project evaluation
negative	*	*	*	*	unacceptable
<=bad	very high	unacceptable	bad	*	unacceptable
<=bad	very high	*	bad	high	unacceptable
<=bad	<=average	unacceptable	bad	high	unacceptable
good	*	acceptable	excellent	low	very good
>=good	high	acceptable	excellent	low	very good
excellent	low	acceptable	good	low	very good
excellent	low	acceptable	>=good	low	excellent

1. Define the problem and determine its goal.
2. Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint; i = 1, …, m ob jectives) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.
3. Construct a set of pair-wise comparison matrices (size n x n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement (for each objective i, compare the j = 1, …, n alternatives and determine their weights aij with respect to objective i).
4. There are n x (n - 1) judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.
5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy (the final alternative weights (priorities) Wj with respect to all the objectives by $W_j = a_{1j}w_1 + a_{2j}w_2 + \ldots + a_{mj}w_m$).
6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, CI as follows: $CI = (\lambda_{max} - n) / (n - 1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI. The CR is acceptable, if it does not exceed 0.10.

The alternatives are then ordered by the Wj, with the most preferred alternative having the largest Wj. The EC software allows us to enter the data for each alternative into the so-called Data Grid, where individual objectives can be entered directly. In this case the intensities or possible qualitative values of decision attributes at the lowest level in the hierarchy are compared in the pair wise comparison matrix (and not the alternatives). This feature enables the usage of the same qualitative scales for qualitative attributes as in the DEX-i model. The data (attribute values) is the entered for each alternative. The use of the Data Grid combines the power of the hierarchy and the pair-wise comparison process with the ability to evaluate hundreds or even thousands of alternatives that would be difficult to compare in pair wise comparison matrix. Alternatives priorities are established relatively to each covering objective by using ratio scaled rating intensities (scales).

A real-world case

The real organic part time farm in north east Slovenia was considered to apply KARSIM EKO 1.0 and MCDA methods using the presented methodological approach. In order to perform analysis 3 business alternatives on sample part time organic farm were selected:

- the alternative 1 (80% of apples and 20% of plum on 2 ha grassland orchard) presented apple and plum processing into apple cider, apple vinegar and plum brandy,
- the alternative 2 presented apple and plum processing into apple cider and plum brandy and
- the alternative 3 presented the combination of dry fruit (apple) and plum brandy.

RESULTS AND DISCUSSION

In the first phase for every analyzed business alternative the costs are calculated using the KARSIM EKO 1.0. In the second phase the CBA was conducted for 15 years at 14% discount rate (Table 4). The CBA results show the financial feasibility of business alternatives; assuming that expected prices and yields would be achieved and that products would be successfully marketed.

The simulation results were further evaluated with multi-attribute decision model (DEX – i and AHP). Since the main results from a simulation model are numerical (investment financial indicators and labor input) the qualitative values must be assigned to each quantitative parameter in order to enable further analysis in DEX – i decision model. This is conducted with classification algorithm based on classification intervals.

Table 4. The results of financial CBA analysis of business alternatives on a sample organic farm

	Alternative 1	Alternative 2	Alternative 3
Investment costs (€)	7 512	1 761	11 492
NPV (€)	4 934	2 920	101
Labor (hours)	1 391	996	1 179
Ranking of alternatives	**1**	**2**	**3**

The DEX - i and AHP evaluation of alternatives (table 5 and 6) result in same ranking of alternatives (alternative 1, alternative 3, alternative 2). These ranking differs from CBA ranking (alternative 1, alternative 2, alternative 3). The ranking of alternatives based on DEX - i and AHP is in this case the same. However, the AHP produces more detailed ranking which can be useful when the alternatives are close to each other and would probably produce the same qualitative DEX - i evaluation. Therefore, the applied AHP methodology should bring unequivocal clarity to the decision which business alternative should be favored and implemented on a sample part time organic farm (Table 6). The AHP does not exclude any alternatives it only ranks them according to the defined hierarchy and relative importance of decision criteria. On the contrary, using DEX - i expert system it can be defined which combination of attribute values is not acceptable for the decision maker. Thus, the DEX - i assessment can be used for exclusion of "unacceptable" alternatives, but the shortcoming of DEX - i is its inability (in contrast to AHP) to separate between alternatives with the same qualitative evaluation.

Table 5. DEX – i project evaluation of business alternatives with importance weights of aggregate attributes

Attribute	Alternative 1	Alternative2	Alternative 3
Investment project appraisal	**very good**	**acceptable**	**good**
Financial indicators (*W=44,7 %)	**excellent**	**good**	**excellent**
NPV	very high	high	very high
Investment costs	low	low	low
Labor intensity (*W=6,4 %)	**very high**	**very high**	**very high**
Technological requirements (*W=11,9 %)	**unacceptable**	**unacceptable**	**unacceptable**
Equipment requirements	very demanding	demanding	very demanding
Processing process	average	demanding	demanding
Market objective (*W=24,4%)	**excellent**	**average**	**good**
Risk objective (*W=12,6%)	**low**	**low**	**low**
Spring frost probability	average	average	average
Hailstone dangerous	low	low	low
Ranking	**1**	**3**	**2**

Table 6. The Expert Choice AHP business alternatives evaluation for the sample organic farm

	Financial objective	Labor intensity	Technological objective	Market objective	Risk objective		Ranking
Weight (W^a)	0.438	0.065	0.122	0.245	0.130		
			a^b			**$\sum Wa^c$**	
Alternative 1	0.396	0.230	0.333	0.573	0.333	**0.413**	**1**
Alternative 2	0.169	0.540	0.333	0.191	0.333	**0.240**	**3**
Alternative 3	0.435	0.347	0.333	0.236	0.333	**0.347**	**2**

W^a - weight; a^b - alternative priority, $\sum Wa^c$ - alternative priority with respect to individual objective (objectives with no sub-levels are assed directly from pair wise comparison matrices)

CONCLUSIONS

The integrated simulation model KARSIM EKO 1.0 combined with multi-criteria decision analysis present the suitable methodological tool for decision support system on organic farms. The system takes into consideration different independent criteria and enables ranking of farm business alternatives. The real value of presented decision model is in its capability to conduct different kinds of "what if" analysis in farm food processing projects. The use of both MCDA approaches can bring additional information into the decision-making framework (for instance the "unacceptable" alternatives can be excluded with the use of the DEX - i model, while the precise ranking of remaining alternatives is based strictly on the AHP Expert Choice model). In presented paper both MCDA methods favored alternative 1, which got the highest DEX – i and AHP (EC) evaluation. The application of the proposed decision support system (combination of KARSIM EKO 1.0, AHP and DEX - i model) would increase the accuracy of information needed for developing farm business plans and that in addition it would help preventing many inappropriate decisions being made on organic farms.

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