SIMULATION MODEL FOR ECONOMIC ANALYSIS IN ORGANIC AGRICULTURE

Karmen PAŽEK[1] and Martin PAVLOVIČ[2]

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Abstract
The simulation system KARSIM 1.0 consists of 148 deterministic production simulation models that enable different types of economic and financial feasibility evaluation for organic production and food processing. The KARSIM 1.0 was applied on a sample organic farm for the simulation of 3 different business alternatives. The simulation model results are further evaluated with two methods: analytical hierarchical process (Expert Choice Decision Support System software) and DEX-i expert system. Business alternative 3 (spelt grain processing) results with the highest multi-objective decision evaluation (Expert Choice = 0.275 and DEX-i evaluation = very good).
Key words: simulation model, KARSIM 1.0, MCDA, DEX-i, Analytical hierarchical process, Expert Choice, transition to organic farming.

SIMULACIJSKI MODEL ZA GOSPODARSKO PRESOJO EKOLOŠKE PRIDELAVE

Izvleček
Sistem simulacije KARSIM 1.0 sestavlja 148 determinističnih proizvodnih simulacijskih modelov, ki omogočajo oceno ekonomike in finančne upravičenosti investicije za ekološko pridelavo in predelavo hrane. KARSIM 1.0 je bil testiran na vzorčni ekološki kmetiji s simulacijo treh različnih poslovnih možnosti. Rezultati simulacijskega modela so nadalje ovrednoteni z dvema metodama: (i) analitičnim hierarhičnim procesom AHP (programska oprema strokovnjakom za podporo pri izbiri) in (ii) ekspertnim sistemom DEX-i. poslovna alternativa 3 (predelava pire) prejme najvišjo oceno večkriterijskega odločitvenega ocenjevanja (strokovna izbira = 0,275 in ocena DEX-i = zelo dobra).
Ključne besede: simulacijski model, KARSIM 1.0, MCDA, DEX-i, analitični hierarhični proces, izbira strokovnjakov, prehod na ekološko kmetovanje

[1] Prof. PhD., University of Maribor, Faculty of Agriculture and Life Sciences Maribor, Pivola 10, 2311 Hoče, Slovenia, e-mail: karmen.pazek@um.si
[2] Prof. PhD., the same address, e-mail: martin.pavlovic@um.si

1 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 till 2007 3.3% of the agricultural area and 3.2% of the farms in the EU. However, the total area under organic farming in the EU continues to increase, and in 2017 covered 12.6 million hectares of agricultural land. Organic area made up 7% of total EU agricultural land in 2017 (FiBL, 2019).

Converting to organic production necessitates changes in farm management which in turn can be expected to have consequences for a farm's characteristics and output. In order to plan a transition to organic production, basic information about expected changes in all framework is required. i.e. management of soil fertility in the organic crop rotations is one of important concept in organic agriculture (Doltra et al., 2019). The economics of transition and its consequences have been closely studied by Nauta et al. (2005) and different modelling approaches have been used such as model enterprise budgets. On the other side determining the market potential and exploring consumers preference for the "transitional" label could help farmers to market their products better and receive the financial rewards during the three-year traditional period. This would not only provide a financial reward to those in transition but also motivate more farmers who were hesitating about adopting the organic operations to make the change and adopt organic farming (Chen et al, 2018). In the last two decades, computer simulation has become an indispensable tool for understanding the dynamics of business systems (Kljajić et al., 2000). Experiences described in literature (Hester & Cacho, 2003; Recio et al., 2003; De Toro & Hansson, 2003; Lisson et al., 2003 & Romera et al., 2003, Rozman et al., 2013) emphasize that a variety of agricultural problems can be solved with computer modelling.

The article describes the methodology and procedure of implementation of cost simulation method in combination with MCDA for solving the organic farm planning problem for the 3 business alternatives.

2 MATERIALS AND METHODS

2.1 Integrated deterministic simulation model KARSIM 1.0

For the financial and technological analyses of the organic production on Slovene farms, the integrated deterministic computer simulation model KARSIM 1.0 was developed. The model consists of 74 sub-models representing each organic crop, animal, and fruit production with related processing products. The sub-models are based upon deterministic technologic-economic simulation (Csaki, 1985; Rozman et al. 2002; Pažek, 2004). Technical relations in the system are expressed with a set of equations or with functional relationships.

The whole system represents a complex calculation system. Through a special interface, the system enables simulation of different business alternatives at a farm level. Furthermore, based on enterprise budgets, cash flow projections can be conducted together with investment costs (Cost Benefit Analysis, CBA) for each business alternative, and the net present values (NPV) for each simulated alternative can be computed. All iterations (calculations for individual alternative) are saved into a database, which is finally used as one of the data sources for multi-criteria analysis. The simulation system is built in an Excel spreadsheet environment and upgraded with the Visual Basic code in order to ensure better functionality of a user-friendly calculation system.

2.2 The DEX-i multi-attribute decision model

The goal of a DEX-i decision model development is to provide answers which business alternative is the best solution for the given sample organic farm. In the first stage of DEX-i decision model development, the possible alternatives are identified (the alternatives are described in section 2.4) and the problem is decomposed into individual less complex problems (hierarchical tree of objectives – criteria).

The financial objective is composed into Net Present Value and Investment costs. Individual business alternatives can be related to different investment costs and therefore connected to the availability of farm investment capital, which as such represents one of the main constrains in the farm. Therefore, investment costs are included into the hierarchy. The human labor objective includes home and hired labor intensity. The technological objective is constructed from equipment and proceeding process requirements. The market objective is described as consumers' preference to an individual product related to each business alternative. The last objective is called risk and includes sensitivity of each alternative to spring frosts and hailstones.

In the next step, each attribute must be assigned with a set of qualitative values (scales). The database of alternatives generated by DSM is used for derivation of qualitative values for each attribute. Since simulation results are numerical, the categorization based on users' defined categorization rules must be performed. For instance, the categorization, for NPV is demonstrated using the following algorithm:

" if NPV > A and NPV < B then NPV is assigned with qualitative value C "

Where: A - lower boundary of a categorization interval, B - upper boundary of a categorization interval, C - qualitative value for {A…B} interval

Table 1: *Categorization table for numerically measured attributes.*

Investment costs (€)	Qualitative Values
0-1000 1,001-3,000 3,001-6,000 6,001-9,000 9,001-12,000 > 12,000	Very low Low Average High Extra high Extremely high
NPV (€)	
0-5,000 5,001-10,000 10,001-20,000 > 20,000	Low Average High Extra high
Human labor (hours)	
0-50 51-100 101-200 > 200	Low Average High Very high
Equipment requirements (equipment)	
0-2 3-4 5-6 > 6	Simple Average Demanding Very demanding
Process (steps in processing technique)	
0-5 6-10 11-15 > 1	Simple Average Demanding Very demanding

The numerical attributes for the DEX-i analysis were obtained by simulation using DSM, while the non-numerical attributes (Table 1) were estimated based on different data sources (i.e., past selling experiences). The following qualitative scales were used for non-numerical sub-attributes (Table 2).

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

After each attribute has been assigned with its scales (qualitative value), the utility functions (knowledge base) are defined. This procedure 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).

Table 3: *Decision rules for organic farm planning problem.*

Financial objective	Human labor intensity	Technological objective	Market objective	Risk objective	Project evaluation
negative	*	*	*	*	unacceptable
<=bad	very high	*	poor	*	unacceptable
<=bad	<=high	unacceptable	poor	*	unacceptable
<=bad	<=average	*	poor	high	unacceptable
<=bad	*	unacceptable	poor	high	unacceptable
<=good	very high	unacceptable	poor	high	unacceptable
good	>=high	acceptable	excellent	low	very good
>=good	high; average	acceptable	excellent	low	very good
excellent	low	acceptable	excellent	low	excellent

The decision rules are presented in complex form where the asterisk "*" means any value and >= equal or better (table 3). The relative importance of attributes can also be expressed by importance weights. In the DEX – i Expert System the estimation of weights is conducted either by multiple regression (the decision rules are interpreted as a set of points in a multidimensional space and approximated with the hyperplane) or by measure of normativity, a measure used in machine learning algorithms to identify most relevant attributes (Bohanec et al, 2000). Finally, attribute values for each alternative are put into the DEX-i evaluation table and the analysis is ultimately conducted.

2.3 The evaluation of alternatives with the Analytical Hierarchical Process

The Analytical Hierarchal Process (AHP) is best illustrated by Saaty (2008). The AHP is a decision support tool, which can be used for solving complex decision problems. It uses a multi-level hierarchical structure of objectives, sub-objectives, and alternatives. The variants are decomposed into specific parameters (criterion, attribute) and evaluated separately for each single parameter. Pros and cons as well as other influencing factors can be included as well. The final variant evaluation is provided with combine proceeding. Ratio comparisons are performed on a fixed ratio scale. The goal is defined as a statement of the overall objectives.

2.4 Selection of a sample organic farm and business alternatives

A sample organic farm in Northeast Slovenia was considered to apply the KARSIM 1.0, the DEX-i expert system, and the Expert Choice multi-objective decision model. The sample farm is a mixed organic farm (size = 10 ha) with a combination of field crop, livestock and fruit production from a traditional grassland orchard. The organic farm regularly includes spelt, oil pumpkins, and buckwheat into crop rotation. Following business alternatives were identified:

Alternative 1: Traditional grassland orchard fruit processing. The average size of a grassland orchard is 2 ha (50% of apples, 30% of plums and 20% of pears). Possible processed organic fruit products are: apple vine, apple juice, apple cider, apple brandy, dry fruit (apples, plums and pears), and plum brandy.

Alternative 2: Goat milk processing into cheese (100 milking goats, average annual milkiness per goat 650 l).

Alternative 3: Spelt processing (the average annual harvest of un-husked spelt grain produced on 1 ha is 2,500 kg) into two equal share of spelt products – spelt grain and spelt flour.

3 RESULTS AND DISCUSSION

The identified transition scenarios (see section 2.4) were evaluated with integrated DSM KARSIM 1.0 and the multi-objective models developed in DEX-i and AHP. In the first step, a financial CBA was computed for five different business alternatives on the organic farm. It should be mentioned here that the CBA was computed for 10 years at a 5% discount rate. The model also enables technological analysis – i.e. calculation of main inputs used, such as human labor (Table 4).

The CBA results (at 5% discount rate and after 10 years) show financial feasibility of alternatives 1 and 3 while alternative 2 is, at given simulation input parameters, not financially feasible (NPV = - 6,066 €; mainly due to significantly higher investment costs) (Table 4).

Table 4: *DSM results (NPV calculated at a 5% discount rate; investment period of 10 years).*

	Alternative 1	Alternative 2	Alternative 3
Investment costs (€)	4,942	41,492	2,917
NPV (€)	5,088	-6,066	10,461

The highest NPV value was observed for traditional grassland fruit processing (alternative 1), followed by spelt grain (NPV = 10,461 €), pumpkin oil (NPV = 5,895 €), and buckwheat processing (NPV = 2,540 €). A relatively high NPV value for alternative 1 can be explained by higher selling prices of different fruit products and higher quantity of processed fruit products that can be produced (apple cider, juice, dry fruit, apple wine, plum brandy). In the next step the results of a simulation were further evaluated using the presented MCDA approach.

In addition to the CBA analysis, the KARSIM 1.0 model provides many technical data for each project. This data is further used for evaluation of some attributes' values. Numerical attribute values (qualitative as input for the DEX-i and AHP decision model) are assessed automatically by the KARSIM 1.0 computer model (based on the user defined costs intervals). The remaining attribute values are determined by the analyst, i.e. decision-maker. The assessment of sub-attributes NPV, investment costs, equipment, food processing techniques, and labor intensity was conducted by the computer model automatically according to the user defined categorization rules (Table 1). The sub-attributes spring frost probability and hailstone frequency and market objectives were assessed analytically (Table 5).

Table 5: *DEX-i evaluation results for food processing business alternatives on the sample organic farm with importance weights of aggregate attributes.*

Attribute	Alternative 1	Alternative 2	Alternative 3
Alternative evaluation:	*good*	*unacceptable*	*very good*
Financial objective (*W=42.6%)	excellent	negative	good
Net Present Value	very high	negative	high
Investment costs	average	extreme high	low
Human labor intensity (*W=7.3%)	very high	very high	high
Technological objectives (*W=11.8%)	unacceptable	unacceptable	acceptable
Equipment	very demanding	demanding	average
Food processing technology	very demanding	very demanding	average
Market objective (*W=25.0%)	good	average	excellent
Risk objective (*W=13.4%)	low	low	low
Spring frost probability	average	low	low
Hails frequency	low	low	low

As shown in table 5, **alternative 3** (spelt grain processing into two different spelt products) ranks with the highest project evaluation (very good), followed by **alternative 1** (good). **Alternative 2** (goat milk processing) yields with the lowest DEX-i assessment. The reason is in negative assessment of financial objectives (the estimated NPV value for this alternative was negative and according to the defined decision rules, any attribute value combination with a negative NPV value is to be rated as unacceptable; Table 3).

The applied AHP methodology should bring unequivocal clarity to the decision which food processing or business alternative should be favored and implemented on an organic farm (Table 6).

Table 6: *Total priority calculations for the sample organic farm.*

	Financial objective	Market objective	Technologic. objective	Risk objective	Human labor objective	Total
Weight (W)	**0.415**	**0.259**	**0.117**	**0.132**	**0.077**	
						∑Wa
Alternative 1	0.396	0.218	0.063	0.201	0.078	**0.260**
Alternative 2	0.072	0.090	0.063	0.201	0.045	**0.091**
Alternative 3	0.272	0.384	0.149	0.257	0.150	**0.275**

*W – weight, *a - alternative priority, * ∑Wa - total alternative priority

4 CONCLUSIONS

The most suitable alternative in the research is alternative 3 (spelt grain processing), which got the highest EC evaluation (0.275), followed by alternative 1 (0.260), and finally alternative 2, which yields with the lowest evaluation (0.091). Compared to another applied MCDA decision approach (DEX-i), the AHP based Expert Choice model presents more detailed, but similar ranking of alternatives. The relative importance weights of aggregate attributes derived by AHP (as results of pair-wise comparisons) and DEX-i (derived on the basis of analyst estimated decision rules) are principally not different (Table 5). Furthermore, the AHP allows us to manage inconsistencies in pair-wise judgements, while inconsistencies in decision rules can sometimes be difficult to find, especially in the case of a very large number of decision rules (in the observed case there are 256 decision rules for the business project evaluation). On the other hand, the DEX-i with its qualitative modelling and the ability to handle inaccurate and/or incomplete data about options appears to be particularly convenient for decision problems that involve qualitative concepts and a great share of expert judgments. Likewise, the DEX-i assessment can be used for exclusion of “unacceptable” alternatives (as demonstrated in Table 3). In contrast, the AHP evaluation results in a single number (total priority) and does not exclude any alternatives. The shortcoming of DEX-i is also its inability (in contrast to AHP) to separate between alternatives with the same qualitative evaluation. The use of both 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). It should also be noted here that both MCDA methods favored alternative 3, while for alternative 1 the highest estimated NPV was revealed.

Further research could be made in combinations with the AHP resource allocation theory (Forman and Selly, 2002), where calculated priorities could be used for optimal allocation of organic farm resources at constrained investment capital; naturally the AHP hierarchy should be changed correspondingly. The categorization of numerical data (transformation of numerical attributes into qualitative scales (in this particular case user defined intervals were used) should be additionally examined (Žnidaršič et al., 2003). The proposed approach would also be suitable for simulation of different scenarios of transition of conventional farm into organic (DSM) and their multi-objective evaluation (DEX-i and AHP). Likewise, the decision model should be interrelated to the marketing information system (marketing attribute).

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