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LEVI 3.0 – MULTIPLE CRITERIA EVALUATION PROGRAM FOR CONSTRUCTION SOLUTIONS

Edmundas Kazimieras Zavadskas[1], Leonas Ustinovičius[1], Zenonas Turskis[1], Friedel Peldschus[2], Danny Messing[2]

[1] *Dept of Construction Technology and Management, Vilnius Gediminas Technical University. Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: leonasu@st.vtu.lt*

[2] *Leipzig University of Applied Science, Karl-Liebknecht Straße 132, 04277 Leipzig, Germany*

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Abstract. The paper considers the main methods employed to solve one-sided and two-sided problems of the game theory. For the one-sided problems only the method of solution "distance to the ideal point" is discussed. For the two-sided problems a distinction is made between games with rational behaviour and games against nature. The main principles of the strategies are as follows: simple min-max principle, extended min-max principle, Wald's rule, Savage criterion, Hurwicz's rule, Laplace's rule, Bayes's rule, Hodges-Lehmann rule. The questions transforming the decision-making matrix are considered: vectorial transformation, linear transformation, linear transformation according to Jüttler's or Stopp's method, non-linear transformation according to Peldschus. The article gives the description of a program package as well as an example of an investment variant estimation. The program LEVI 3.0 is a result of the cooperation between the VGTU and HTWK. This article provides description of a program package as well as an example of investment variant estimation to illustrate the application of methods described; efficiency problem of financial investment in construction or reconstruction in the health resort of Nida (Lithuania) is analysed.

Keywords: game theory, decision-making matrix, linear transformation, non-linear transformation, multiple criteria evaluation, one-sided problems, two-sided problems, estimation of investment efficiency.

1. Introduction

The economy can grow successfully only being open. Expenses for production to pursue profit in future (investment) are very significant for the economy growth. They must be increased and used in the most efficient way. Investments must be evaluated for creating new investment projects or for decision of the following problems:

1) To evaluate a specific project;
2) To motivate participation in a specific project;
3) To compare specific projects and to select the best one.

Insufficient substantiation of projects efficiency under increased risk (open market) prevents from potential investments. State, private businessmen, credit institutions financing real investment projects are concerned about the quality of project evaluation [1]. The main problem of efficiency evaluation is to determine and to ground whether implanting the project (certain civil, financial and other similar design) is "useful", "profitable" or vice versa "useless", "unprofitable", "unrational".

K.Train presents a comprehensive general review of existing methods and certifies [2] that in the 1980s there were delivered the main models of qualitative selection analysis and their defined statistic and economic properties. These methods were successfully applied in many fields, including transportation, energetics, civil engineering and market (enumerated a few only). He presents the development directions and ways of modern methods too. A lot of procedures are created in this field. Recent works of V. Kalinka and S. Frant offer a multistage decision-making procedure for evaluating energy production in Israel. In this decision-making process are participating: a person drawing conclusions (agent) and a computer. Paretto, Topsis, Lexgraph methods [3] are used. C. Parkan and M. L. Wu [4] investigate variants of "the distance to the ideal point" methods; M. Ben-Akiva, D. Bolduc and J. Walker [5] investigate logit methods.

The evaluation of alternatives according to multiple criteria computer programs used at present: DELFI, ELECTRE III, ELECTRE IV, PREFCALC, MAPPAC, CARTESIA, PROMCALC, etc. Takes place at present ELECTRE [6], UTA [7, 8], MAPPAC [9–11], CARTESIA [12], PROMETHEE [13, 14] methods are used in these programs.

Program "DELFI" has been created and applied by the USA Defence Ministry to solve the problems of evaluation of experts' opinion. Details are not presented.

Programs "ELECTRE III" and "ELECTRE IV" are similar. Fluctuations of meanings (insignificant, permissible, impermissible) are defined according to the meanings of given criteria. Results include accordance, reliability and final comparable matrixes, final rearranged values and priority vector. Results are influenced by partial results which may be changed.

Program "PREFCALC" employs the UTA method. Array of possible variants of evaluation is chosen according to the given criteria values on determining the maximal and minimal value boundaries and giving the linear segment number of usefulness. The variants are evaluated according to the rank and scale of evaluation. The program gives additional usefulness function conformed with decision maker (agent) priorities. Priority vector conformed with determined usefulness function is the final result. The results are under the influence of all the above-mentioned information that may be changed.

Program "MAPPAC". Two priority vectors, corresponding rationality differences and increasing or decreasing sort base are given after processing data according to given criteria values, directions of priorities, available maximal and minimal boundaries, significances, relative significance values for every pair of criteria or absolute values of significance, priorities of agent, more exactly defined threshold values of criteria equivalency and each criteria pair equivalency threshold functions. The result is presented as a vector of available variants priorities and as their graphical image. By the graphic image it is possible to determine the definition functions of variants.

Program "IDRA". Analyses of given values of criteria, directions of criteria priorities, maximal and minimal boundaries provides a priority vector, graphic image, partial domination matrix and priorities of main indexes after processing data.

Program "CARTESIA". It presents effective compensation resources for each pair of available variants a_r and a_s, available interval of the criteria changes. In this interval is true that variant a_r in future will be better than variant a_s. Program includes information about potential compensation, partial compensation power, absolute compensation power, compensation indicator and effective compensation power to each criteria pair.

At present main results are in the field of modelling (simulation) [2]. This field rapidly develops due to computers inability to perform integration procedures. A more exactly determined simulation according to different methods results in numerical approximations of integrals. Advantages or disadvantages and connections between advantages and disadvantages of various methods are very important for selecting a solution method of individual problems. Otherwise, data must be computer processed to implement new methods.

Agent (a person or firm making decisions) is in a permanent collision with series of choices or mistakes concerning the effect of various conditions set. The best global usefulness function of problem solution depends on the agent's information, problem's aim and object's model.

When analysing well-known programs, it is possible to state that authors of programs mostly choose one problem's solution method and one way of decision-making matrix transformation [15–17]. Results obtained in this way are hardly comparable. Up to now there are no rules how to use multi-criteria evaluation methods and how to interpret the solution results [18–23]. Therefore the solution of this problem must be found.

Vilnius Gediminas Technical University (VGTU) and the Leipzig University of Applied Sciences (HTWK) have been investigating the application of games theory methods to the building technology and management problems for more than 30 years. The program LEVI 3.0 is a result of the cooperation between the VGTU and HTKW. Due to the different approaches the two institutions used different methods. The common aim has always been the evaluation of an optimal variant of the problem. With new software it is possible to find solution of rational strategy problem using different methods under risk and uncertainty and to compare the results.

The game theory and its methods are instruments for developing the theory of technological behaviour [24, 25]. It has been shown that the problems of building technology and management precisely correspond to the games of two persons with zero sums. Some practical solutions of the rational investment problems are presented.

Solution results enable a more exact investigation, creation of interpretation regulations and choosing more precise solution method. Obtained results of investigation can make a basis for creating new solution methods.

2. Application of the program Levi 3.0

At is has been mentioned, the program LEVI 3.0 is a result of the cooperation between two institutions (Fig 1, 2, 3). Due to different approaches two institutions used different methods. The common aim of both methods was to choose an optimal variant for civil engineering process and investments. In this new created software there are possibilities with once introduced data to solve problem using different solution methods and decision-making matrix transformation ways.

A distinction is made between one-sided and two-sided problems for the solution methods. The one-sided problems are solved using well-known methods of selection and the determination of an order of precedence. Using the game theory, the two-sided question aims at finding the equilibrium as a result of the rational behaviour of two parties having opposite interests or at

Fig 1. Program's Levi information window

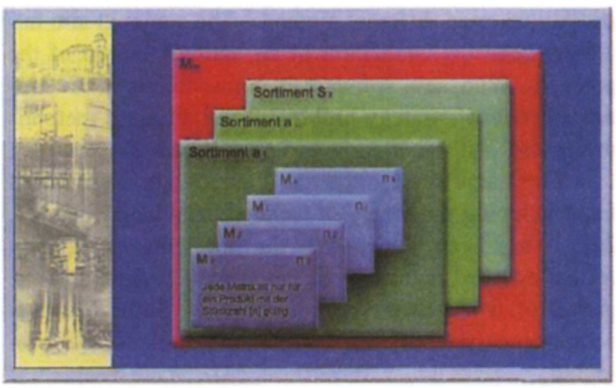

Fig 2. Serial operating window of the program LEVI 3.0

Fig 3. Contacts information window of the program LEVI 3.0

the equilibrium in a game against nature. The one-sided problems standpoint is oriented to several well-known methods choice of variants and rank sequence determination. This program enables to use weightings for criteria.

Program LEVI 3.0 enables us to solve production series problems (Fig 4). Using weighted matrix the various products with different number of pieces production optimal variant can be found. A requirement exists that all products can be manufactured with the same variants of production.

Program is written using "Delphi 6" programming language and can work under Windows 98, Millennium or higher operating system. It is possible to use various criteria (number in program is limited ≤ 50), and many variants (the number of program is limited ≤ 50). Friendly oriented help function is included in this program.

The review of useful information about the applied in program solution methods, decision-making matrix transformation ways and data print properties are included in the help menu.

One of the achievements is that the decision-matrix transformation ways and a solution method are not tightly related and a relative independence is presented.

All important functions (Save, Open, Significance factors, Solution methods, ...), the software can be controlled by the upper collection of menu.

In all dialog fields after the click <**F1**> or <?> calling button enables "Help". This program works under Window 98 and can be adapted to English or German languages.

3. Investigation of solution methods and decision-making matrix transformation ways

To illustrate application of the described methods, we shall consider the task of investments in construction. The task of efficiency of financial investments in reconstruction or construction in a health resort Nida (Lithuania) was analysed. The number of investment variants was limited by requirements for reserve area and conservation of architectural monuments. Consequently, three investment variants were actually considered. It is possible to build a residential building or a hotel in the centre of the town, or a residential building at the seaside. Specific requirements for architecture in the centre of the town increase the construction cost. On the other hand, price of the project implementation is higher in comparison with other urban areas. The hotel variant assumes partial maintenance and further sale. Efficiency of the variant was evaluated by the following effectiveness indices: duration of project implementation, cost price of the project (site or building acquisition cost, cost of designing, erection and assembly work), selling price of the project, predicted profit. Bank interest rates were taken into account while calculating the amount of profit. Table 1 below provides the basic data.

All projects cost price was reduced to one year and to 1 000 000 LTL.

$$k_2 = k_5 / k_4;$$

where k_5 is project selling price, k_4 – project cost price. Also as a criterion, criterion ratio predicted profit (k_6) to project cost price (k_4) was determined:

$$k_3 = k_6 / k_4;$$

After the above-mentioned replacements we have a decision-making matrix (Table 2).

Table 1. Main data for evaluation of investments effectiveness

Variant		Project's implementat duration	Project's cost price	Project's selling price	Predicted profit
	Measure	Years	LTL	LTL	LTL
	Marking	k_1	k_4	k_5	k_6
V_1	Apartments in the centre of the town	1,5	4335000	7200000	2415000
V_2	Hotel with partial mainte-nance	8,5	5200000	6500000	4200000
V_3	Apart-ments at the seaside	1,3	3400000	4800000	1780000
	Optimisation direction	min	min	max	max

The first criterion must be minimised. The second and third criteria must be maximised. Three optimal values are in different variants. Criterion 1 has minimal value in variant 1; criterion 2 has maximal value in variant 1 and for the criterion 3 in the variant 2 has maximal value (Fig 5).

Table 2. Decision-making matrix

	k_1	k_2	k_3
v_1	1,500	1,661	0,557
v_2	8,500	1,250	0,808
v_3	1,300	1,411	0,524
	min	max	max

Different transformation methods of initial decision-making matrix were used (Fig 6):

- Transformation through normalisation of vectors;
- Linear transformation;
- Non-linear according to Peldschus.

Different problem solution methods were used:

- distance to the ideal point;
- simple min-max principle,
- Wald's rule,
- Savage criterion,
- Hurwicz's rule,
- Laplace's rule,
- Bayes's rule,
- Hodges-Lehmann rule.

The problem was solved including and not including the criteria weightings. Solution results are given in Figs 7–9 and comparison of results in Table 3.

If to the most preferable variant we set 1 point, to the second – 2 points ant to the third – 3 points, then to

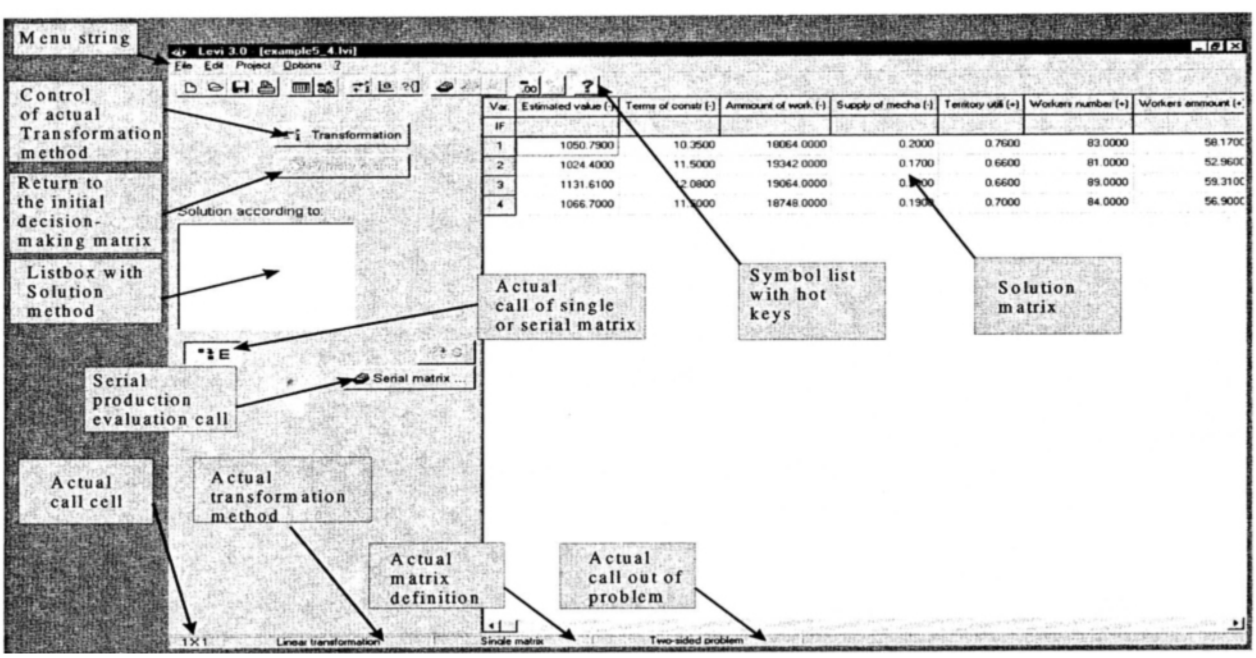

Fig 4. Destination of the information field

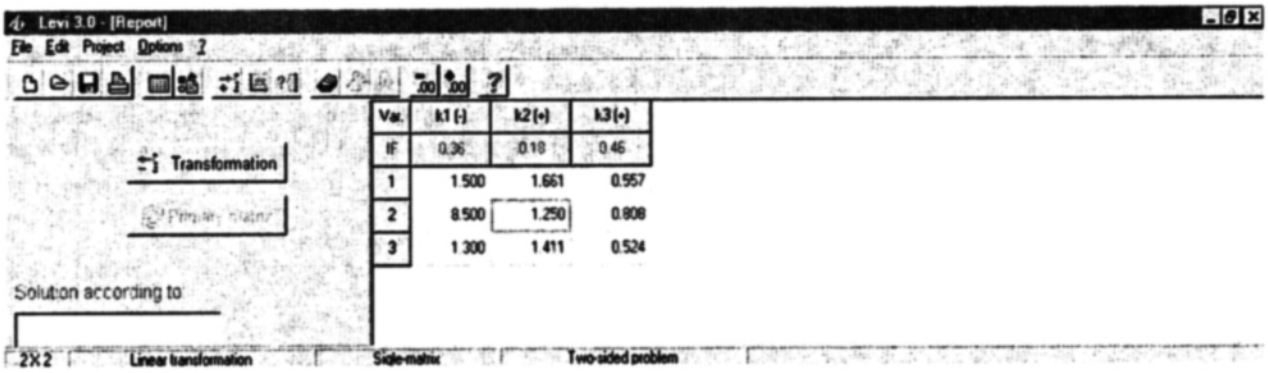

Fig 5. Structure of the input data

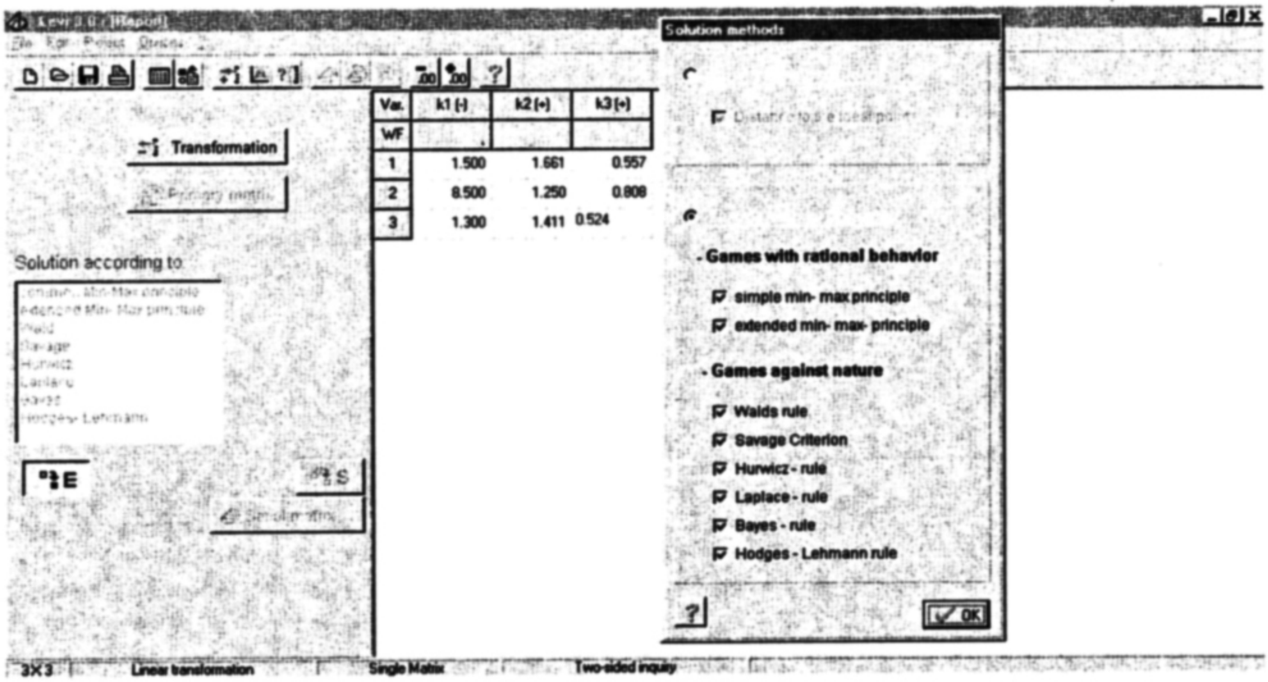

Fig 6. Input of the solution methods

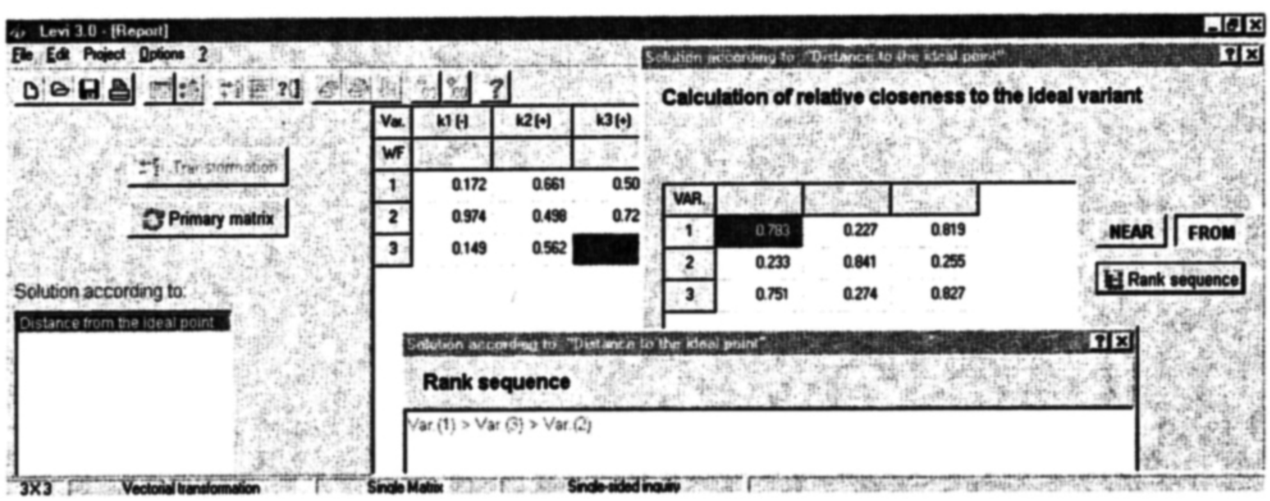

Fig 7. Solution results of the one-sided problems

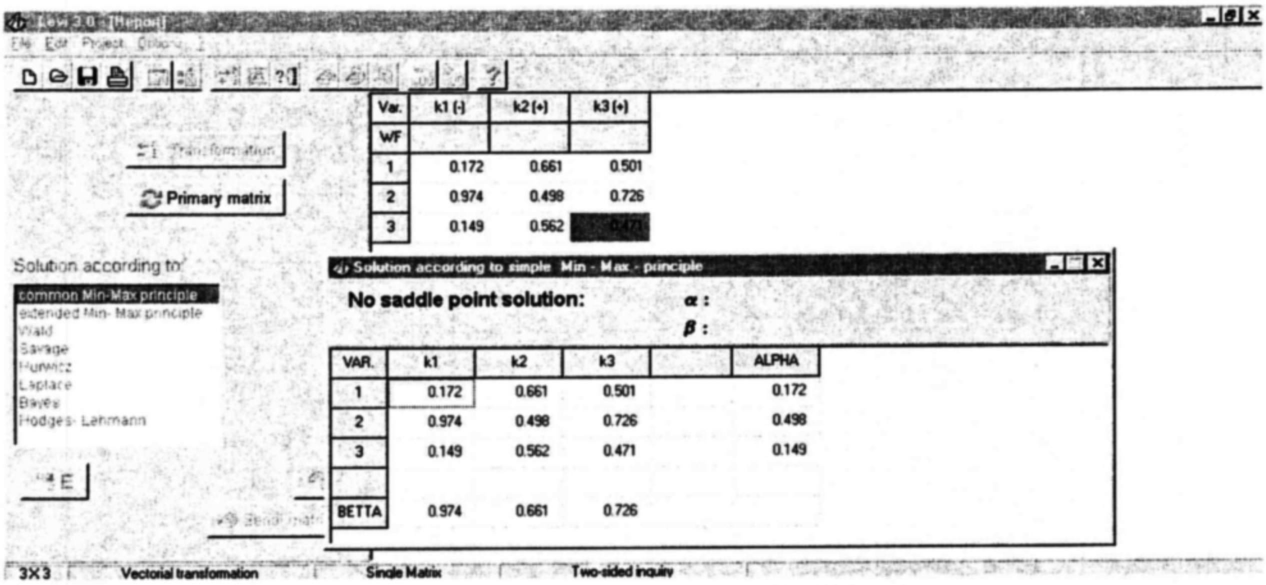

Fig 8. Solution results of the two-sided problems

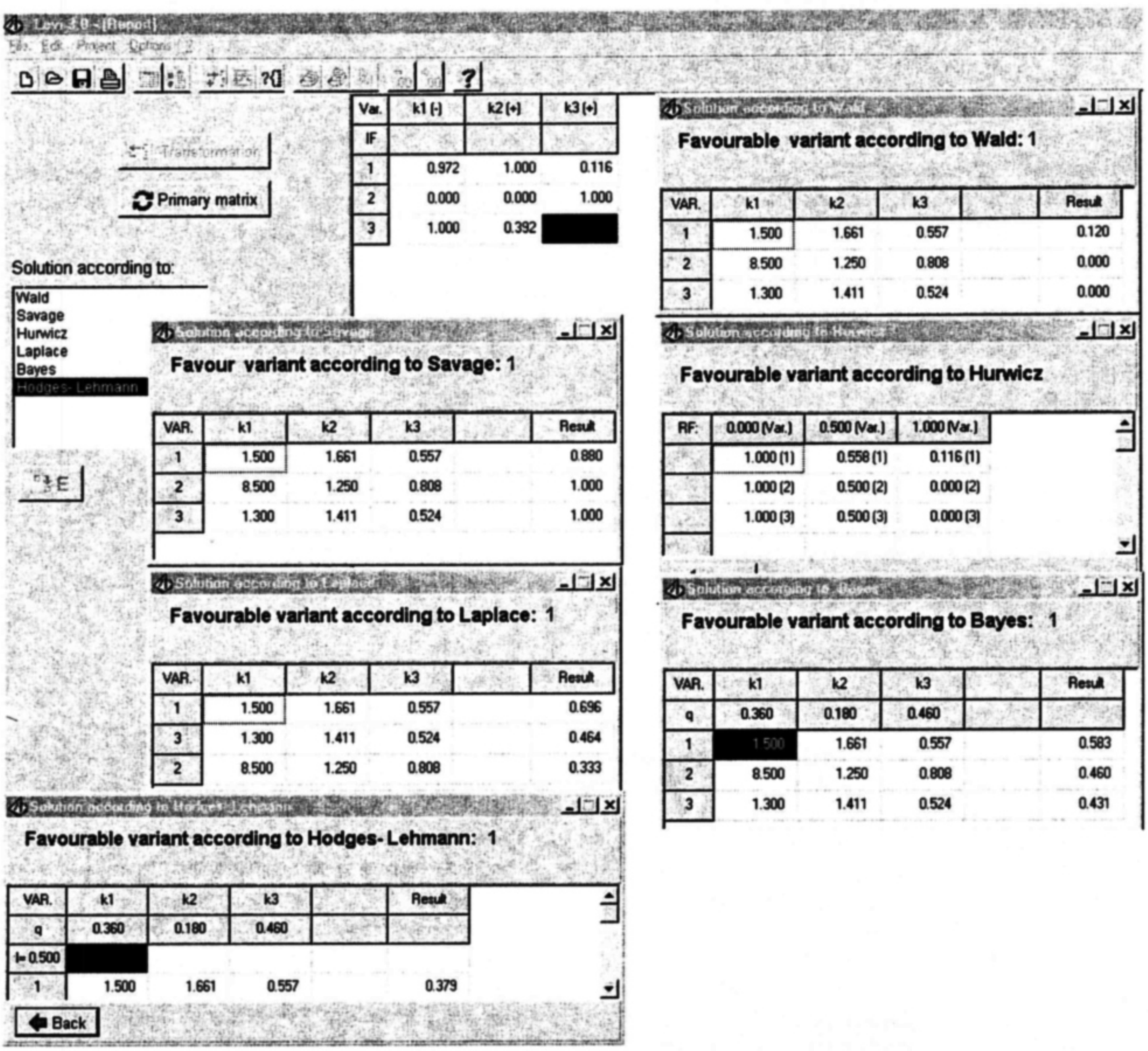

Fig 9. Best alternative according to Wald, Hurwicz, Laplace, Bayes, Hodges-Lehmann rules and Savage criterion

Table 3. Results of solution- established variants rank number

	Solution method	Decision-making matrix's transformation way			
		Not transformed	Vectorial	Linear	Non-linear
Criteria significances (weightings-q) not included	Distance to the ideal point	1>3>2	1>3>2	2>1>3	2>1>3
	Simple min-max principle	2	**	*	*
	Solution according to Wald	2>1>3	2>1>3	1>2>3	1>3>2
	Solution according to Savage	2>1>3	2>1>3	1>2>3	1>3>2
	Solution according to Hurwicz RF 0	2>1>3	2>1>3	1>2>3	1>2>3
	Solution according to Hurwicz RF 0,5	2>1>3	2>1>3	1>2>3	1>3>2
	Solution according to Hurwicz RF 1	2>1>3	1>2>3	1>2>3	1>3>2
	Solution according to Laplace	2>1>3	2>1>3	1>3>2	3>1>2
Criteria significances (weightings-q) included	Distance to the ideal point	3>1>2	3>1>2	3>2>1	3>1>2
	Simple min-max principle	*	**	*	1
	Solution according to Wald	1>3>2	2>1>3	1>2>3	1>3>2
	Solution according to Savage	2>1>3	2>1>3	2>1>3	1>3>2
	Solution according to Hurwicz RF 0	2>1>3	2>1>3	2>3>1	2>3>1
	Solution according to Hurwicz RF 0,5	2>1>3	2>1>3	2>1>3	3>2>1
	Solution according to Hurwicz RF 1	1>3>2	3>1>2	1>2>3	3>1>2
	Solution according to Laplace	2>1>3	2>1>3	1>2>3	3>1>2
	Solution according to Bayes	2>1>3	2>1>3	1>3>2	3>1>2
	Solution according to Hodges-Lehmann	2	2	1	1

** No saddle-point solution; * No saddle-point solution, many-sided solution

the first variant corresponds 44, to the second – 53 and to the third – 74 points (when criteria weightings are included). To the first variant corresponds – 37, the second – 42 and the third – 47 points when criteria weightings are not included.

We get such variants priority set "1>2>3" (that means, that the first variant is better than the second and the third variants, that the second variant is better than the third one).

When criteria weightings are included in the evaluation and analogous set "2>1>3" when criteria weightings in the evaluation are not included (remark: all solution variants under different risk factors are reduced to the mediocre set "1>2>3" when criteria weightings are not included in the evaluation, and "2>1>3" when they are included). According to the analysis results the most effective first variant was realized.

4. Conclusions

The program LEVI was developed for calculating production processes in the building sector. Following the static equilibrium, the equilibrium in the game theory has a particular significance. A comparison of results from different solution methods is necessary because the equilibrium application in the game theory to the building process is not always possible.

The program LEVI has a practical and scientific interest. It is not possible to evaluate the effects of different methods of transformation of decision-making matrix on the numerical result up to now. Another problem is variety of solutions. It causes difficulties for a practical user. These problems are to be solved through the application of the program LEVI.

A practical model for investigating of various methods of solution and of ways of decision-making matrix transformation has been developed

The proposed analytical model may be used for further research by solving problems of analysis and optimisation of civil engineering, economy, etc.

Use of the non-linear transformation improves the quality of transformation of decision-making matrix and allows to solve technological and organizational problems more precisely.

Almost all programming modulus of program LEVI can be applied to creative process of decision-making systems.

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