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ESTIMATION OF OPTIMAL INVESTMENT INTO INFORMATION TECHNOLOGY USING HYBRID MOMC MODEL

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Abstract: *In order to assess and estimate optimal investing into information technology (IT), a study has been done on the benefits and risks of such investments in a business system environment. The goal of reaching this decision will be actualised by identifying the best IT application with respect to estimated investment benefits and risks. In order to solve this problem, we used the hybrid Multi-Objective, Multi-Criteria (MOMC) model. The hybrid MOMC model is one of more recent models for estimating the usefulness of IT, combining whole-number linear goal programming and the Analytic Hierarchy Process (AHP) method. Estimating investments into IT is a complex issue, since quality (or immeasurable) uses and risk factors must be taken into consideration along side quantity (measurable) elements of IT usefulness. Quality and risk factors are difficult to estimate with certainty, as there are no standard measures made for such estimations. In such a case, the estimation demands a general agreement on the metrics of attaching values to quality factors. The hybrid MOMC model is a structural decision-making model allowing decision-makers to identify all quantity, quality and risk factors involved in the particular situation(s) of investing into IT. All these factors are organized through a hierarchy structure and quantified through the AHP. By using the AHP method, decision-maker may determine the levels of priority for all factors (criteria) according to self-estimations of their relative importance as pertaining to investments. The purpose of determining such priority levels and importance is to have the decision-maker preferences fully adjust to the set goal and relative values of investment benefits and risks. Results gained by the AHP methods shall be used as entry values for the model of goal programming and the selection process.*

Keywords: *benefits and risks of investing into IT, estimation of investing into IT, hybrid MOMC model.*

1. INTRODUCTION

Recent research in the field of business value of information technology (IT) and estimates of investing into IT suggest the following [3, p.194]:

1. Assessment of quantity (measurable) and quality (immeasurable) uses should be performed for all types of investments into IT. Even though each type investment into IT may demand a different assessment/estimation emphasis, most investments feature, to some extent, the question of quantity and quality gains.

2. Risk estimation of investing into IT is important in order to ensure that the gains significantly overreach the risks. Most assessment/estimation methods wrongly assume that particular employee skills and control measures will ensure success.

Estimation of quality factors is significantly more complex that that of quantity factors, since there are no standard economic and financial measures made for quality estimation; alternate approaches using quantifying metrics for assessment and estimation of quality are used.

Quality IT values may have an important impact on financial business results of a particular firm. Therefore, such factors must be monitored and measured. They can be monitored through input variables (intangible assets, including investing into software, knowledge, training and a number of changes in organization) and output variables (immeasurable results of IT use, like user satisfaction, diversity of products/services, quality, flexibility, timeliness, etc.)

Since IT is a new, fast-evolving technology, investments into IT may be followed by significant changes in the structure and the overall conduct of firms who made such investments. Not only are the expenses of changes in organization following (augmented) IT use great, but there is also a great chance of failure. If such risks are to be incorporated in calculations, expected expenses of significant restructuring based on IT may be high indeed. A pessimist may be thrown by such organization expenses, while the optimist will probably be happy due to implied assets being made by such a process.

Research collecting the data on benefits and risks of investing into IT applications was done in order to solve the problem of decision-making in the company "DESIGN" (pseudonym). IT applications (IT-1, IT-2, IT-3, IT-4 IT-5, IT-6, IT-7) are all related applications covering the same area of business, but are applications from different manufacturers. The aim of solving the decision-making problem is to generate the optimal IT application with respect to assessed and estimated investment benefits and risks.

Table 1 systematically dissects the criteria (benefits/risks) for the assessment and estimation of investing into IT and contains the data collected on the value of each application under defined criteria. The data on Quantity Benefits for each of the IT applications were obtained from the company's head manager based on certain calculations and according to several criteria, for example: raising productivity, lowering cost, conserving time, cutting staff, etc. Data on quality benefits of particular application use are shown by average values obtained based on answers by questioned managers and users of IT (on scale 1-3: 1=no improvement, 2=moderate improvement, 3=significant improvement). Criteria for the estimation of quality values are: improving the decision-making process, improving process management, IT user satisfaction, possibility of simulations, environment compatibility. Risk factors are shown by appearance probability percentages for each application, and pertain to unrealised benefits/use and additional expenses (education or running late with actualisation of plan(s)).

The hybrid Multi-Objective, Multi-Criteria (MOMC) model was used for assessment and estimation of optimal investing into IT. The hybrid MOMC model is one of more recent models for estimating the usefulness of IT and, as such, contains:

1. *The* Analytic *Hierarchy Process (AHP),* used in order to determine relative criteria values (benefits/risks) of investing into IT, as well as relative values of solution means (IT applications) under each set criterion; in this way the model mimes the human decision-making process and contains an easily understandable mechanism for checking operative inconsistencies when working with quality and risk factors which are difficult to assess and estimate;

2. Whole-*number Linear Goal Programming* (*WLGP*), a model which defines the goal function, decision-making variables and their limits in order to generate the optimal type of investment into IT).

2. DESCRIPTION OF DECISION-MAKING PROBLEM (*GOAL, CRITERIA, TYPES*)

The goal of the decision-making problem solving is to identify the best IT application as pertaining estimated investment benefits and risk. Table 1 shows the collected data on quantity and quality benefits of each IT application, as well as the data on the risks of investing into IT applications. Research and collection of relevant data was done according to the following *Criteria Hierarchy Structure*:

1. Quantity Benefits (i.e. usefulness)

1.1. Increase of productivity

1.1.1. Decrease of total cost of generating information
1.1.2. Expense decrease based on generating new information
1.1.3. Time conservation in information access

1.2. Development of processes

1.2.1. Expense decrease of printing and distribution of documents
1.2.2. Reduction of staff

2. General Quality Benefits

2.1. Improvement of decision-making process

2.1.1. improvement of connectivity and informing
2.1.2. improvement of time and quality of decision-making

2.2. Improvement of process management

2.2.1. improvement of communications
2.2.2. standardisation
2.2.3. improvement of control
2.2.4. increased flexibility
2.2.5. compatibility with consumer systems
2.2.6. more productive use of sales opportunities

2.3. IT user satisfaction

2.3.1. output value
2.3.2. timeliness
2.3.3. reliability
2.3.4. reaction time
2.3.5. exactness
2.3.6. integrity/completeness
2.3.7. ease of use
2.3.8. ease of learning

3. Technological Quality Benefits

3.1. Possibility of simulation

3.1.1. usability of production resources

3.1.2. simulation of financial flow

3.1.3. simulation of plan accomplishment

3.2. Compatibility with environment

3.2.1. business systems

3.2.2. institution systems

4. Risks

4.1. unrealised benefits/usefulness

4.2. additional late penalties (expenses) pertaining to realization due dates

4.3 additional expenses for current employee training

Criteria of higher level decompose into criteria of lower levels, making up a three-level criteria hierarchy within the criteria structure. IT applications (IT-1,IT-2,IT-3,IT-4,IT-5,IT-6,IT-7) are all related applications covering the same area of business, but are applications from different manufacturers. They represent the *solution options* for the decision-making problem.

Table 1: Benefits and risks of investing into IT applications ("Design" company)

			IT1	IT2	IT3	IT4	IT5	IT6	IT7
Quantity benefits (usefulness)	**Increase of productivity**	**Decrease of total cost of generating information**	15800	15800	15700	15750	15750	15700	15800
		Cost savings based on generating new information (cost of additional work hours per week x 52 x hourly rate)	1930	3675	5512	2100	3590	5500	1950
		Time-savings in accessing information (average No. of accesses per week x 52 x average time-savings in hours x hourly rate)	182x52x 0,03x5,30 = 1505	3010	2508	1600	3000	2700	1500
	Advancement of process	**Expense savings in printing and distribution of documents** (average document cost x yearly No. of documents)	0,65x 22000=14300	0,65x24000=15600	0,65x25800=16770	0,65x 23000=14950	0,65x24000=15600	0,65*25000=16250	0,65*23500=15275
		Decreasing number of staff (No. of hours x hourly rate + new employee)	165x5,30+13500=14375	920x5,30+13500=18376	720x5,30+13500=17316	350x5,30+13500=15355	800x5,30+13500=17740	750x5,30+13500=17475	190x5,30+13500=14507
Sum of Quantity Benefits:			**47910**	**56461**	**57806**	**49755**	**55680**	**57625**	**49032**
General Quality Benefits (avg. value)	**Improving decision process**	**Improved connectivity and being informed**	2,4	2,5	2,4	2,4	2,6	2,4	2,3
		Improved time and quality of decisions	2,2	2,4	2,2	2,1	2,3	2,2	2,1
	Improving process management	**Improved communication**	2,3	2,5	2,5	2,4	2,4	2,3	2,3
		Standardisation	2,0	2,1	2,3	2,1	2,2	2,2	2,0
		Improved control	2,2	2,4	2,4	2,1	2,3	2,3	2,2
		Increased flexibility	2,0	2,5	2,4	2,1	2,6	2,5	2,4
		Compatibility with user system	2,2	2,8	2,7	2,3	2,6	2,6	2,1

		More efficient use of sales capabilities	2,0	2,7	2,6	2,1	2,6	2,5	2,2
	IT user satisfaction	Output value	2,2	2,8	2,7	2,2	2,7	2,7	2,1
		Timeliness (on-time)	2,4	2,7	2,7	2,3	2,6	2,6	2,1
		Reliability	2,2	2,9	2,6	2,3	2,8	2,5	2,2
		Reaction time	2,3	2,5	2,5	2,4	2,5	2,5	2,4
		Preciseness	2,1	2,6	2,5	2,2	2,5	2,3	2,2
		Integrity (completeness)	2,4	2,4	2,4	2,3	2,5	2,3	2,3
		Ease of use	2,3	2,7	2,5	2,1	2,8	2,6	2,2
		Ease of learning	2,1	2,8	2,7	2,1	2,8	2,6	2,2
Technological Quality Benefits (avg. value)	Possibility of simulations	Usability of production resources	2,1	2,6	2,4	2,0	2,5	2,3	2,1
		Simulation of financial flow	2,3	2,7	2,5	2,4	2,6	2,5	2,3
		Simulation of plan actualisation	2,2	2,6	2,5	2,1	2,6	2,6	2,2
	Compatibility with environment	Business systems	1,9	2,1	2,1	2,2	2,1	2,0	1,9
		Instutution systems	2,0	2,3	2,2	1,9	2,2	2,1	2,2
Risk Factors	Unrealised benefits (usefulness)		8% x47910 = 3833	4% x56461 = 2258	5% x57806 = 2890	6% x49755 = 2985	4% x 55680 = 2227	5% x57625 = 2881	5% x49032 = 2452
	Additional late penalties (expenses)		7% x12000 = 840	4% x14500 = 580	4% x13000 = 520	6% x13000 = 780	5% x13500= 675	5% x12000 = 600	4% x12500 = 500
	Additional education costs (expenses) (avg.% of probability for all employees x No. of employees x cost of additional education/training)		20%x16x125 = 400	14%x16x125= 280	10%x16x125 = 200	18%x16x125 = 360	15%x16x125 = 300	10%x16x12 5= 200	20%x16x125 = 400

Note: Substitute decimal comma with decimal period!

Characteristics of Quantity Benefits for one year:

- by using new IT applications, one accomplishes **expense savings of generating information**, since the time the staff needs to generate such important information also decreases; generating information without new IT applications would demand more staff; according to calculated savings, applications IT-1, IT-2 and IT-7 have equal value (15,800); applications IT-4 and IT-5 also equal, but lesser value (15,750); and applications IT-3 and IT-6 equal, but lowest value (15,700);

- by using new IT applications, one accomplishes **expense savings stemming from generation of information** (*additional weekly work hours x 52 x hourly rate*); in order to generate additional information using the current IT, one would need to use more time; new IT applications differ in decreasing the need for additional time; according to calculated savings, the most favourable option is IT-3, followed by options IT-6, IT-2, IT-5, IT-4, IT-7, IT-1; we should consider the integrity of the whole system covered by each IT option; application IT-3 covers the greatest business segment; application IT-1 does not fully cover one system segment, so the necessary information is received in the existing manner;

- by using new IT applications, one accomplishes **saving time in accessing information** (*average number of weekly accesses x 52 x average savings per hour x hourly rate*); average savings per hour is based on the comparison with the existing IT; option IT-2 is the most favourable there, followed by IT-5, IT-6, IT-3, IT-4, IT-1, IT-7;

- except productivity elements, using new IT positively influences other elements, such as **expense savings in printing and distribution of documents**; new IT uses electronic documents and records; such savings, based on the comparison to the current IT, say that the best option is IT-3, followed by IT-6, IT-2=IT-5, IT-7, IT-4, and finally, IT-1, which has the lowest value; differences in the number of yearly documents by IT options point to system integrity; it has been mentioned that IT-1 does not fully cover one smaller system segment, while IT-3 covers the largest system segment;

- the next benefit of IT applications is **reducing the number of staff**; new IT in this case does not significantly reduce the number of employees; the company estimates the business will grow, and so will the quantity of data that needs to be processed using IT (some 50% in the next three years); in that case, new IT ensures additional time of current employees freed up for other activities; the most favourable option pertaining to these savings is IT-2, followed by applications IT-5, IT-6, IT-3, IT-4, IT-7, IT-1.

Characteristics of quality benefits for one year:

- quality benefits are expressed in average values obtained based on the answers of questioned persons (IT managers and users) on a scale of 1-3: 1=no improvement, 2=small improvement, 3=significant improvement; one of the benefits is the **improvement of decision process;** this criterion is divided into two sub-criteria: improved connectivity and intake of information, and improved time and quality of decisions; average grades according to *improved connectivity and intake of* *information* criterion were best with IT-5 option, then IT-2, IT-1=IT-3=IT-4=IT-6, and the least favourable was IT-7; when measuring the *improved time and quality of decisions* criterion, the most favourable option was IT-2, followed by IT-5, IT-1=IT-3=IT-6, and finally by IT-4=IT-7;

- the next quality benefit is **improvement of process management,** which breaks down into the following elements: improved communication, standardisation, improved control, increased flexibility, compatibility with user systems, more efficient use of sales possibilities; the best grade under the *increased communication* criterion went to IT-2=IT-3, followed by IT-4=IT-5, and at the end were IT-1=IT-6=IT-7; the winner of the criterion *standardisation* (acceptance of new industrial standards) was IT-3, then IT-5=IT-6, IT-2=IT-4, and at the back, IT-1=IT-7; best grade for *increased control* went to IT-2=IT-3, followed by IT-5=IT-6, IT-1=IT-7, then IT-4; best grade for *increased flexibility* went to IT-5, followed by IT-2=IT-6, IT-3=IT-7, IT-4, while IT-1 had the lowest grade; results for *compatibility with user systems:* IT-2, then IT-3, IT-5=IT-6, IT-4, IT-1 and finally IT-7; *more efficient use of sales possibilities* criterion had a winner in IT-2, followed by IT-3=IT-5, IT-6, then IT-7, IT-4 and at the end, IT-1;

- **IT** user satisfaction is the reflection of their satisfaction with the use of IT, and it is a quality criterion divided into the following sub-criteria: *output value* (the best option for this sub-criterion, according to answers, was IT-2, followed by IT-3=IT-5=IT-6, then IT-1=IT-4, and finally IT-7); *timeliness* (i.e. performing on time - best options were IT-2=IT-3, then IT-5=IT-6, after them IT-1, IT-4, and finally IT-7); *reliability* (best option IT-2, then IT-5, then IT-3, IT-6, IT-4, then IT-1=IT-7); *reaction time* (best options were IT-2=IT-3=IT-5=IT-6, followed by IT-4=IT-7, and finally IT-1); *accuracy* (IT-2 had the highest grade, followed by IT-3=IT-5, IT-6, IT-4=IT-7, and the lowest grade went to IT-1); *entirety* (best grade to IT-5, followed by IT-1=IT-2=IT-3, then IT-4=IT-6=IT-7); *ease of use* (best option was IT-5, then IT-2, then IT-6, IT-3, IT-1, IT-7, and at the end, IT-4); *ease of learning* (best options were IT-2=IT-5, followed by IT-3, IT-6, IT-7, and finally IT-1=IT-4);

- **possibility of simulation** is divided into three sub-criteria: usability of production resources (uncovering bottlenecks), simulation of financial flow and simulation of plan fulfilment; if we look at the criterion *usability of production resources*, the best option was IT-2, followed by IT-5, IT-3, IT-6, then IT-1=IT-7, and finally, the worst grade went to IT-4; the option *simulation of financial flow* had the winner in IT-2, runner-up was IT-5, then IT-3=IT-6, then IT-4, and finally IT-1=IT-7; IT-2=IT-5=IT-6 had best average grades for the option *simulation of plan fulfilment*, followed by IT-3, then IT-1=IT-7, and at the back, IT-4;

- **compatibility with other systems** (possibility of disseminating any type of information through any technological component) is divided into two sub-criteria: *compatibility with business systems* (winners were IT-2=IT-3=IT-5, less beneficial IT-4=IT-6, and least beneficial IT-1=IT-7), and *compatibility with institution systems* (best option was IT-2, followed by IT-3=IT-5, IT-6, then IT-1=IT-7, and the lowest grade went to IT-4).

Characteristics of risk factors for one year:

- investment risks are expressed in percentages of appearance probability for each application; three risk factors were taken in consideration: ***% of unrealised benefit*** (best option IT-5, followed by IT-2, IT-7, IT-6, IT-3, IT-4, and worst option IT-1, since it has the greatest unrealised benefit percentage);
- the next risk factor considered was ***additional late expenses** with regard to operational due dates* (IT-7 was the most favourable option, followed by IT-3, IT-2, IT-6, IT-5, IT-4, and the least favourable was IT-1, since it had the largest additional penalties/expenses);
- the third risk factor are ***additional expenses for existing worker education*** (best options were IT-3=IT-6, then IT-2, IT-5, IT-4, and finally IT-1=IT-7, since they amassed the most additional expenses).

3. ANALYTIC HIERARCHY PROCESS (AHP)

3.1. CHARACTERISTICS OF THE AHP METHOD

The Analytic Hierarchy Process (AHP) is a multi-criteria method of assessment/evaluation which mimes the human decision-making process and verifies consistency in such a process. The AHP contains four main steps [3, p.199]:

1. Shaping the decision-making problem based on hierarchy structuring of inter-connected elements and decision options. The main goal of the problem i.e. the problem of selection and assessment, is decomposed into the hierarchy of inter-connected criteria and sub-criteria.
2. Development of subjective preferences (preference matrices) for each criterion and for each option (application) based on comparison of pairs.
3. Calculation of relative priorities for each decision-making element through a number of numerical calculations (procedures of matrix normalisations).
4. Compiling relative priorities in order to obtain the ranking of decision-making options by priority, which is obtained by calculating the matrix specific deferring vector. This norm vector of the principle of paired matrices is the resulting evaluation (weight) of the corresponding IT option.

Once the hierarchy has been determined, the decision maker begins the procedure of prioritising in order to determine the relative importance of elements on each level. Elements on each level are determined in pairs with respect to their importance for other elements of same level. This constitutes a number of paired comparison matrices starting with the top of the hierarchy and working its way to the lowest levels. During the process of making such matrices, the AHP allows the decision maker to verbally express his or her preference between the two elements in each pair in the following manner: equally important (or preferred, or probable), somewhat more important (or preferred), significantly more important, much more important, or extremely more important. Such expressions are converted into numerical ranks: 1,3,5,7 and 9, where 2,4,6 and 8 are intermediate values for compromises between two successive quality assessments [1, p.112]. Decision maker is allowed to changed his "preferences" and to test the results if the inconsistency level should be very high. It is assumed that evaluations of relative importances are consistent enough if the inconsistency ratio is less than 0.10.

Results obtained using the AHP method shall be used as input for the model of goal programming and the selection process. It is clear that IT assessment and evaluation is a complex problem, and the decision maker is faced with many possibilities of giving inconsistent input or making a number of other mistakes. The AHP process allows the decision maker to measure and inspect his process assessment inputs and ranking. In this way, the hybrid model allows the process of assessment and selection to mimic the human decision-making process in a correct manner.

The model is based on two multi-criteria shaping approaches which supplement each other well during the process. One approach relates to objective data (Quantity Benefits), and the other to subjective data (Quality Benefits and Risk Factors).

3.2. DETERMINATION OF RELATIVE VALUES OF IT APPLICATIONS BY FIRST LEVEL CRITERIA

Hierarchy structure of criteria for our decision-making problem encompasses three criteria levels. First level criteria are: Quantity Benefits (**KVANT**), General Quality Benefits (**OKVAL**), Technological Quality Benefits (**TKVAL**) and Risk (**RIZ**).

According to earlier mentioned AHP method steps and the use of Expert Choice software, this chapter deals with the description of the model of decision-making problem structured by hierarchy, including the first level criteria and 7 IT applications evaluated by each criterion. In other words, the structure of the decision-making problem according to this model has one criteria level (first level criteria) and the level of subordinate applications (to these criteria).

The evaluation of the ratio of relative importances for first level criteria are defined according to the Saaty scale, which is, in turn, used to form the matrix of weight (importance) ratio (the preference matrix). Table 2 shows the matrix of importance ratios for first level criteria.

Table 2: Matrix of importance ratios for first level criteria

	KVANT	OKVAL	TKVAL	RIZ
KVANT		1/3	1/3	1/3
OKVAL			3	1
TKVAL				1/3
RIZ				

Each value in the matrix represents intensity importance and has a certain meaning. For example, the result of the KVANT and OKVAL ratio is 1/3 meaning that General Quality Benefits criterion is given the nod in relation to Quantity Benefits. Comparing OKVAL and TKVAL gives the advantage to General Quality Benefits in relation to Technological Quality Benefits (value of 3).

During the process of determining the criteria importance ratios, transitivity may be damaged, i.e. inconsistencies may spring up in the assessment of importance value ratios. Therefore, the inconsistency ratio for each criteria group being assessed should also be known. Based on data entered, the program determines first level criteria weight (importance) (Fig. 1).

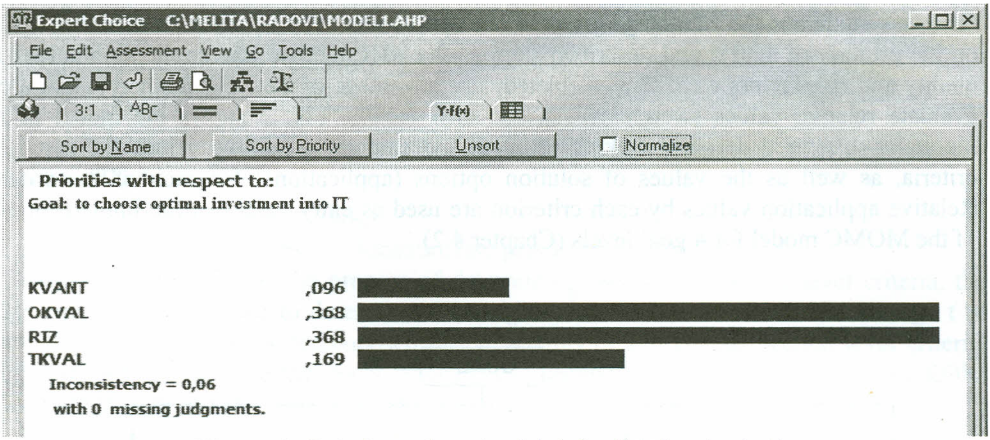


Figure 1: Relative values (weight) for first level criteria
(note: substitute decimal comma with decimal period)

Analogue to this, application value for each criterion is also measured. Application priority determination by each criterion is achieved based on the analysis of data found in Table 1. For example, by analysing the sum of Quantity Benefits of each application (Table 1, row: Sum of Quantity Benefits), we determine the application priority by the KVANT criterion (Quantity Benefits). The antecedence is given to one application as compared to another, finally generating the preference matrix. Based on the preference matrix, the software calculates the weights (values) of applications according to KVANT criterion. The weight of the KVANT criterion (0.096) is decomposed to weights of subordinate applications. Fig. 2 shows the calculated values (*local priorities*) of IT applications for the KVANT criterion.

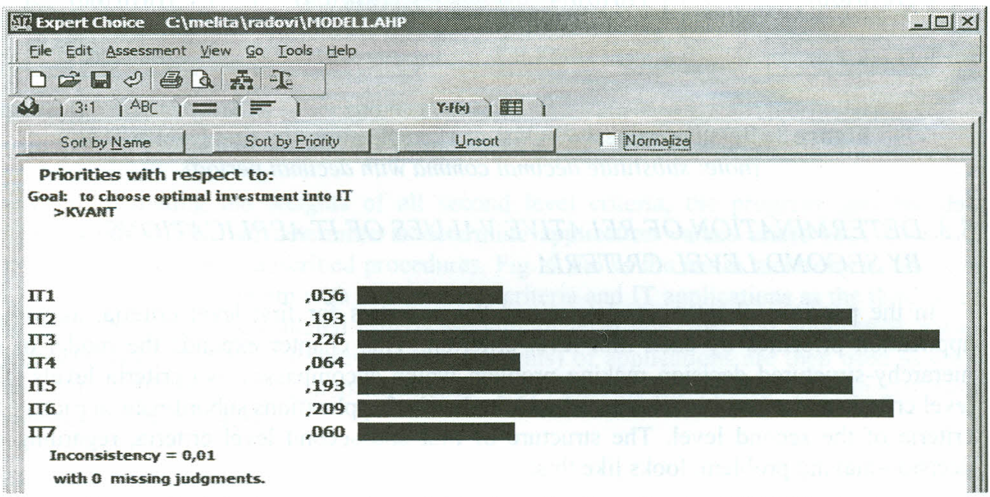


Figure 2: Relative values (weights) of applications for the KVANT criterion
(note: substitute decimal comma with decimal period)

Analogue to this, using the AHP method one determines the weights of applications for other first level criteria (quality benefits and risk). As can be seen in Table 1, quality benefits of applications are tough to evaluate using mathematical calculations. In order to evaluate and generate preference matrices for quality and risk factors, average values and percentages were analysed (answers by persons questioned in Table 1), based on which the option (application) ratio was made and the advantage given to one application in comparison to the other. Based on the preference matrix and described steps of the AHP method, the application values for quality and risk factors were also calculated. The advantage of the AHP method is that it can evaluate relative values (weights) even for such factors. Fig. 3 shows the model of the hierarchy-structured decision making problem and calculated relative values for first level criteria, as well as the values of solution options (applications) for each of the criteria. Relative application values by each criterion are used as entry values in the implementation of the MOMC model for 4 goal levels (Chapter 4.2).

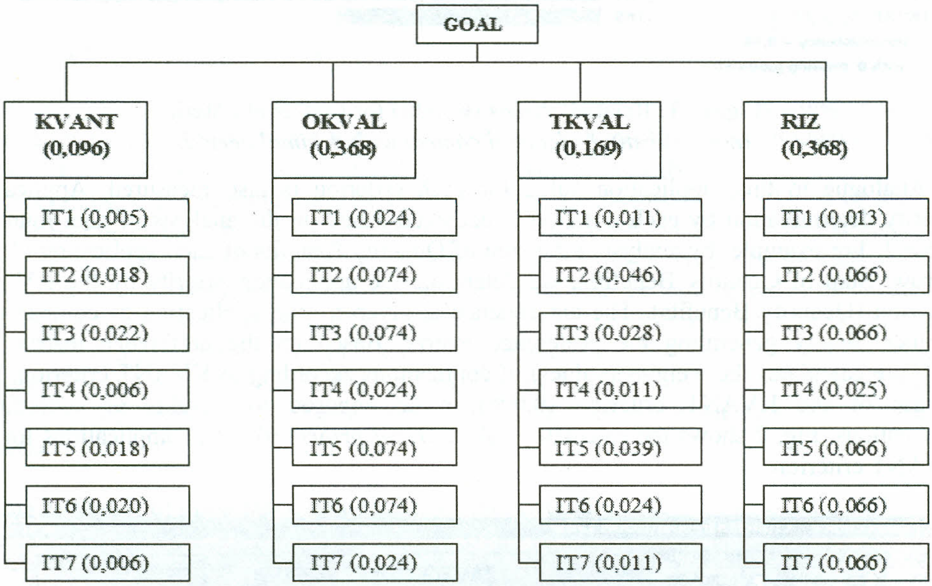


Figure 3: Relative values(weights) of IT applications by first level criteria
(note: substitute decimal comma with decimal period)

3.3. DETERMINATION OF RELATIVE VALUES OF IT APPLICATIONS BY SECOND LEVEL CRITERIA

In the previous chapter we determined the priorities for first level criteria, as well as application priorities by each first level criterion. This chapter expands the model of the hierarchy-structured decision making problem which encompasses two criteria levels (first level criteria and second level criteria) and the level of applications subordinate to each of the criteria of the second level. The structure of first and second level criteria, regarding our decision-making problem, looks like this:

1. **Quantity Benefits (KVANT)**
   1.1. Increase of productivity (PROD)
   1.2. Advancement of process (PROC)

2. **General Quality Benefits (OKVAL)**
   2.1. Improvement of decision process (ODL)
   2.2. Improvement of process management (UPR)

2.3. IT user satisfaction (KOR)

3. Technological Quality Benefits (TKVAL)

3.1. Possibility of simulation(s) (SIM)
3.2. Compatibility with environment (KOMP)

4. Risks (RIZ)

4.1. Unrealised benefits (NK)
4.2. Additional expenses (education, late penalties) (TRO)

In the same manner as the process of determining the weight of first level criteria, the AHP method can be used to determine the weight of second level criteria. The weigh t of each first level criterion is decomposed to the weights of subordinate second level criteria. Fig. 4 shows relative weights (*local priorities*) of second level criteria (ODL, UPR, KOR) which are all subordinate to OKVAL at the first level.

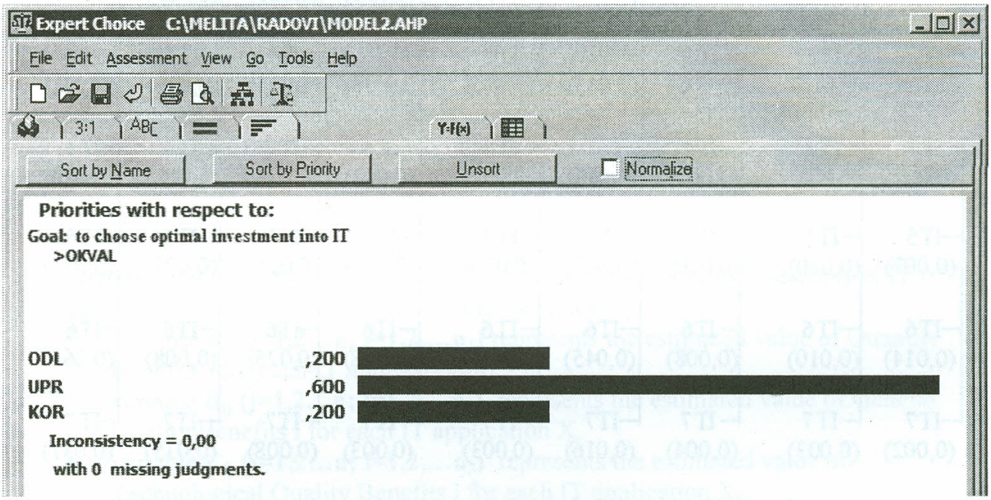


Figure 4: Relative weights of second level criteria subordinate to OKVAL criterion
(note: substitute decimal comma with decimal period)

After calculating the weights of all second level criteria, the program uses the data analysis from Table 1 to determine to determine application values under each level two criteria using previously described procedures. Fig. 5 shows the entire hierarchy structure of the decision-making problem with two levels of criteria and IT applications as the third level. The figure also shows calculated criteria weights of level one, two and application values under second level criteria. Relative values (weights) of applications are then used as entry values for MOMC model implementation into goal levels which encompass more components (Chapter 4.3).

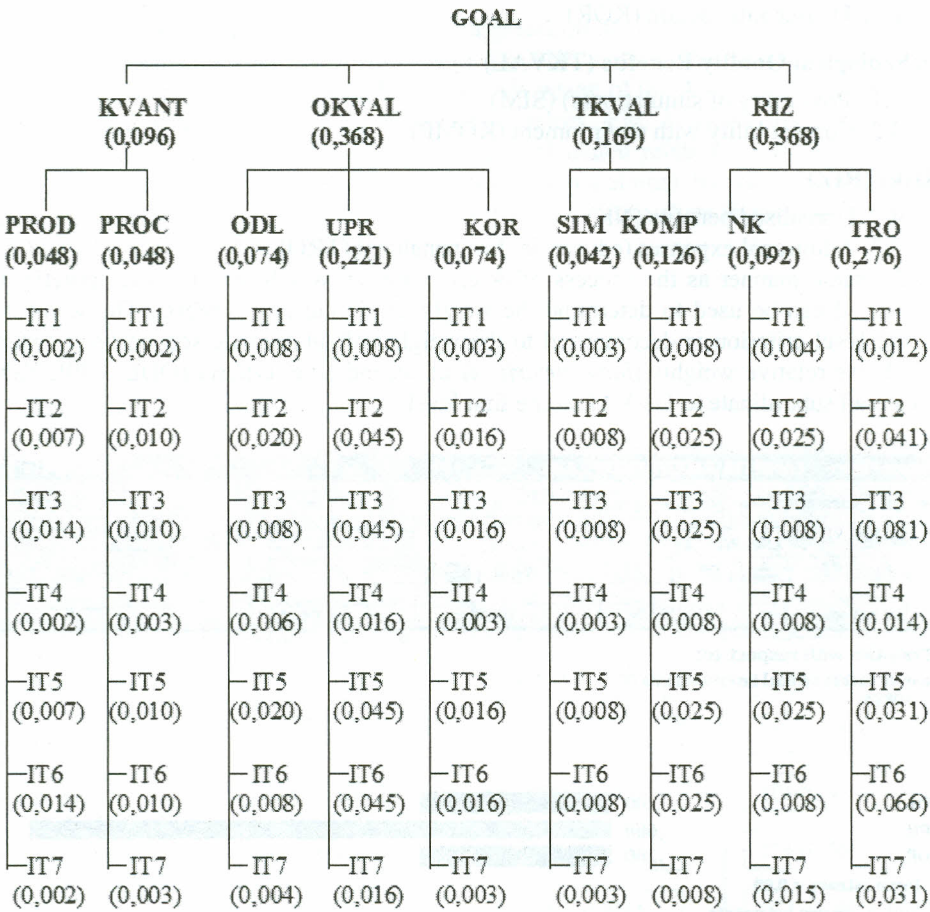


Figure 5: Relative values (weights) of IT applications by second level criteria
(note: substitute decimal comma with decimal period)

4. MOMC MODEL IMPLEMENTATION IN ASSESSMENT AND EVALUATION OF OPTIMAL IT INVESTMENT

4.1. DESCRIPTION OF GOAL PROGRAMMING MODEL VARIABLES

The aim of the model is to identify the most beneficial IT application with respect to evaluated benefits and risks of investing into IT.

Decision Variables are IT applications X_j (j=1,2….7). X_j are integer variables.

X_j= 1 if the IT application is accepted;
X_j= 0 if the IT application is not accepted.

Variable n: the number of IT options being considered. In our case n= 7 since 7 IT applications are being tested.
Variable n_1: the number of Quantity Benefit components used in the evaluation;
Variable n_2: the number of General Quality Benefit components used in the evaluation;
Variable n_3: the number of Technological Quality Benefit components used in

the evaluation;

Variable n_4: the number of Risk Factor components used in the evaluation.

Variables representing goal levels (levels we are aiming for) are as follows:

1. variable $\mathbf{K_i}$ represents the goal level for quantity benefits (i.e. usefulness) **i** ($i=1,2,\ldots n_1$);
2. variable $\mathbf{OK_i}$ represents the goal level for general quality benefits **i** ($i=1,2,\ldots n_2$);
3. variable $\mathbf{TK_i}$ represents the goal level for technological quality benefits **i** ($i=1,2,\ldots n_3$);
4. variable $\mathbf{R_i}$ represents the goal level for the risk factor **i** ($i=1,2,\ldots n_4$).

Deviation variables (representing deviation) from set goal levels are as follows:

1. variables $\mathbf{K_i^+}$ i $\mathbf{K_i^-}$ represent positive (over-reach) and negative (under-reach) deviations from Quality Benefits **i;**
2. variables $\mathbf{Op_i^+}$ i $\mathbf{Op_i^-}$ represent positive (over-reach) and negative (under-reach) deviations from General Quality Benefits **i;**
3. variables $\mathbf{T_i^+}$ i $\mathbf{T_i^-}$ represent positive (over-reach) and negative (under-reach) deviations from Technological Quality Benefits **i;**
4. variables $\mathbf{R_i^+}$ i $\mathbf{R_i^-}$ represent positive (over-reach) and negative (under-reach) deviations from Risk **i.**

Assessed and evaluated benefits and risks (*results of AHP implementation*) of IT applications are represented by the following variables:

1. variable $\mathbf{A_{ij}}$ **($j=1,2\ldots n$; $i=1,2,\ldots n_1$)** represents the estimated value of Quantity Benefits **i** for each IT application X_j;
2. variable $\mathbf{B_{ij}}$ **($j=1,2\ldots n$; $i=1,2,\ldots n_2$)** represents the estimated value of General Quality Benefits **i** for each IT application X_j;
3. variable $\mathbf{C_{ij}}$ **($j=1,2\ldots n$; $i=1,2,\ldots n_3$)** represents the estimated value of Technological Quality Benefits **i** for each IT application X_j;
4. variable $\mathbf{D_{ij}}$ **($j=1,2\ldots n$; $i=1,2,\ldots n_4$)** represents the estimated value of Risk Factor **i** for each IT application X_j.

<u>**The Goal Function**</u> minimizes the sum of deviation from goal levels and has the following form:

$$\text{Min}\Big(\sum_{i=1}^{n1}(PK_i^+K_i^+ + PK_i^-K_i^-) + \sum_{i=1}^{n2}(POp_i^+Op_i^+ + POp_i^-Op_i^-) + \sum_{i=1}^{n3}(PT_i^+T_i^+ + PT_i^-T_i^-) + \sum_{i=1}^{n4}(PR_i^+R_i^+ + PR_i^-R_i^-)\Big)$$

Deviation weights are tied to priorities of set goals according to decision maker's wishes. Weights (values) are represented by the following variables:

1. for Quantity Benefits **i**, the Deviation weight is represented by variables $\mathbf{PK_i^+}$ i $\mathbf{PK_i^-}$;
2. for General Quality Benefits **i**, the Deviation weight is represented by variables $\mathbf{POp_i^+}$ i $\mathbf{POp_i^-}$;

3. for Technological Quality Benefits **i**, the Deviation weight is represented by variables $\mathbf{PT_i^+}$ i $\mathbf{PT_i^-}$
4. for Risk Factor **i**, the Deviation weight is represented by variables $\mathbf{PR_i^+}$ i $\mathbf{PR_i^-}$.

Limitations of the **Quantity Benefits goal i** may be represented by the function:

$$(1) \quad \sum_{j=1}^{n} A_{ij}X_j - K_i^+ + K_i^- = K_i \text{ for } i = 1,2.........n_1$$

Limitations of the **General Quality Benefits goal i** may be represented by the function:

$$(2) \quad \sum_{j=1}^{n} B_{ij}X_j - Op_i^+ + Op_i^- = OK_i \text{ for } i = 1,2.........n_2$$

Limitations of the **Technological Quality Benefits goal i** may be represented by the function:

$$(3) \quad \sum_{j=1}^{n} C_{ij}X_j - T_i^+ + T_i^- = TK_i \text{ for } i = 1,2.........n_3$$

Limitations of the **Risk Factor goal i** may be represented by the function:

$$(4) \quad \sum_{j=1}^{n} D_{ij}X_j - R_i^+ + R_i^- = R_i \text{ for } i = 1,2.........n_4$$

$$(5) \quad X_j = (0 \text{ or } 1)$$

$$(6) \quad X_1 + X_2 + X_3 + ... + X_n = 1$$

4.2. IMPLEMENTATION OF MOMC MODEL FOR 4 GOAL LEVELS

According to described MOMC model variables, we conclude we have 7 decision variables (7 IT applications). By using the AHP method, we calculated the relative value (weight) for each application for first level criteria (Fig. 3) and for second level criteria (Fig. 5). In the implementation of the MOMC model for 4 goal levels (4 first level criteria), calculated application values represent the estimates benefits/risk of each application by each of the four criteria. They are described by variables $\mathbf{A_{ij}}$, $\mathbf{B_{ij}}$, $\mathbf{C_{ij}}$ and $\mathbf{D_{ij}}$. Since in this implementation the goal levels do not decompose to subordinate components, the following is true: $n_1=n_2=n_3=n_4=1$; index *i* does not change value, and the index *j* changes its value from 1 to 7, since we are using seven applications.

In the implementation of the MOMC model, the decision maker sets the goal level, i.e. goal priority he would like the optimal IT application to satisfy for each criterion (benefits/risk). The goal level by criteria is based on the highest calculated value (priority) of application for the came criterion. Therefore, the following **goal levels** are set in the model:

1. K = 0.022 (KVANT)
2. OK = 0.074 (OKVAL)
3. TK = 0.046 (TKVAL)
4. R = 0.066 (RIZ)

For deviation weights from the goal levels, it needs to be stressed that **each positive deviation (higher application priority) from set goals (priorities) will be acceptable for**

the decision maker, while each negative deviation will be unacceptable to the decision maker. All acceptable deviations are valued at 0, and unacceptable are labelled with 1-10.

$$\mathbf{PK^+ = POp^+ = PT^+ = PR^+ = 0}$$
$$\mathbf{PK^- = POp^- = PT^- = PR^- = 1}$$

The general formula for the Goal Function is:

$$\text{Min}\ \left(\sum_{i=1}^{n1}(PK_i^+K_i^+ + PK_i^-K_i^-) + \sum_{i=1}^{n2}(POp_i^+Op_i^+ + POp_i^-Op_i^-) + \sum_{i=1}^{n3}(PT_i^+T_i^+ + PT_i^-T_i^-) + \sum_{i=1}^{n4}(PR_i^+R_i^+ + PR_i^-R_i^-)\right)$$

By inserting the values of deviation weights in the general formula, we reach the following form of the Goal Function:

Goal Function for 4 goal levels:

$$\text{Min}\ (PK^-K^- + POp^-Op^- + PT^-T^- + PR^-R^-)$$

According to limitations as set in Chapter 4.1 (formulae (1)-(6)), the equation system for the model of goal programming (in our case $\mathbf{n_1= n_2= n_3= n_4=1}$) has the following form:

Limitations:

(1) $\mathbf{\sum_{j=1}^{7} A_jX_j - K^+ + K^- = K}$

$$0.005X_1 + 0.018X_2 + 0.022X_3 + 0.006X_4 + 0.018X_5 + 0.020X_6 + 0.006X_7 - K^+ + K^- = 0.022$$

(2) $\mathbf{\sum_{j=1}^{7} B_jX_j - Op^+ + Op^- = OK}$

$$0.024X_1 + 0.074X_2 + 0.074X_3 + 0.024X_4 + 0.074X_5 + 0.074X_6 + 0.024X_7 - Op^+ + Op^- = 0.074$$

(3) $\mathbf{\sum_{j=1}^{7} C_jX_j - T^+ + T^- = TK}$

$$0.011X_1 + 0.046X_2 + 0.028X_3 + 0.011X_4 + 0.039X_5 + 0.024X_6 + 0.011X_7 - T^+ + T^- = 0.046$$

(4) $\mathbf{\sum_{j=1}^{7} D_jX_j - R^+ + R^- = R}$

$$0.013X_1 + 0.066X_2 + 0.066X_3 + 0.025X_4 + 0.066X_5 + 0.066X_6 + 0.066X_7 - R^+ + R^- = 0.066$$

The model is implemented into *excel spreadsheet* software, which has the tools for integer linear goal programming. Fig. 6 shows the dialogue window of the tool for defining parameters and options in order to solve the decision-making problem.

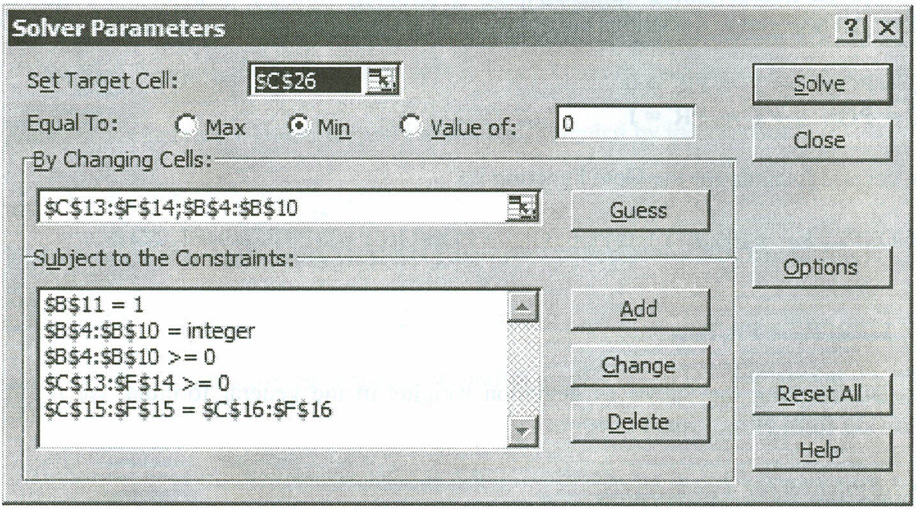
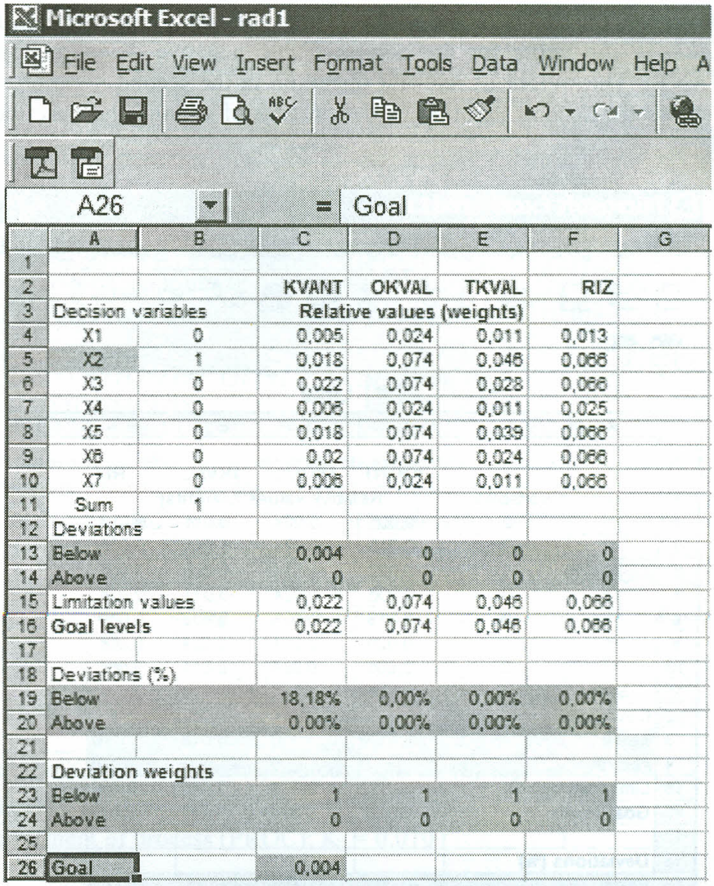


Figure 6: Dialogue window for integer linear goal programming

After defining the parameters and options, and after we have imputed the values and formulae for the model of integer linear goal programming into the software tool, the program *solver* generates the optimal solution. Fig. 7 shows the first iteration in solving the described decision-making problem.



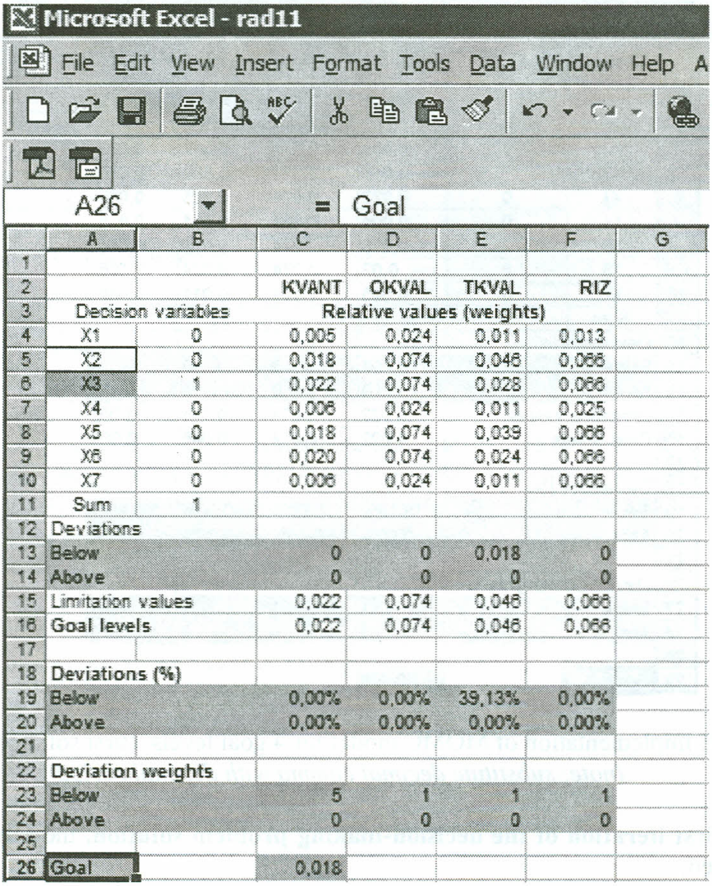
	A	B	C	D	E	F	G
1							
2			KVANT	OKVAL	TKVAL	RIZ	
3	Decision variables		Relative values (weights)				
4	X1	0	0,005	0,024	0,011	0,013	
5	X2	1	0,018	0,074	0,046	0,066	
6	X3	0	0,022	0,074	0,028	0,066	
7	X4	0	0,006	0,024	0,011	0,025	
8	X5	0	0,018	0,074	0,039	0,066	
9	X6	0	0,02	0,074	0,024	0,066	
10	X7	0	0,006	0,024	0,011	0,066	
11	Sum	1					
12	Deviations						
13	Below		0,004	0	0	0	
14	Above		0	0	0	0	
15	Limitation values		0,022	0,074	0,046	0,066	
16	Goal levels		0,022	0,074	0,046	0,066	
17							
18	Deviations (%)						
19	Below		18,18%	0,00%	0,00%	0,00%	
20	Above		0,00%	0,00%	0,00%	0,00%	
21							
22	Deviation weights						
23	Below		1	1	1	1	
24	Above		0	0	0	0	
25							
26	Goal		0,004				

Figure 7: Implementation of MOMC model for 4 goal levels (first solution iteration)
(note: substitute decimal comma with decimal period)

In the first iteration of the decision-making problem solution, the following values were obtained:

- **the most favourable IT application** vis-a-vis estimated investment benefits and risks and their coordination with the set goals **is the application X_2** i.e. X_2=1, X_1= X_3= X_4= X_5= X_6= X_7=0;
- deviations from Quantity Benefit K^- are 18.18% (goal level K=0.022);
- deviations from General Quality Benefits Op^+ and Op^- are 0% (goal level Op=0.074);
- deviations from Technological Quality Benefits T^+ and T^- are 0% (goal level T=0.046);
- deviations from Risk Factors R^+ and R^- are 0% (goal level R=0.066);
- value of the Goal Function (minimum deviation sum) is 0.004.

Obtained result corresponds to all goal levels ($Op^+ = Op^- = T^+ = T^- = R^+ = R^- = 0\%$), except the goal level for the Quantity Benefits level K^- = 18.18%. If the decision maker does not accept such deviation, i.e. this iteration as the optimal solution of the problem, ***the decision maker may change the value*** for the corresponding negative deviation from Quantity Benefits (KVANT). The weight of relevant deviation in the second iteration solution will be 5. Fig. 8 shows the second iteration in the process of solving the described decision-making problem.



	A	B	C	D	E	F	G
1							
2			KVANT	OKVAL	TKVAL	RIZ	
3	Decision variables		Relative values (weights)				
4	X1	0	0,005	0,024	0,011	0,013	
5	X2	0	0,018	0,074	0,046	0,066	
6	X3	1	0,022	0,074	0,028	0,066	
7	X4	0	0,006	0,024	0,011	0,025	
8	X5	0	0,018	0,074	0,039	0,066	
9	X6	0	0,020	0,074	0,024	0,066	
10	X7	0	0,006	0,024	0,011	0,066	
11	Sum	1					
12	Deviations						
13	Below		0	0	0,018	0	
14	Above		0	0	0	0	
15	Limitation values		0,022	0,074	0,046	0,066	
16	Goal levels		0,022	0,074	0,046	0,066	
17							
18	Deviations (%)						
19	Below		0,00%	0,00%	39,13%	0,00%	
20	Above		0,00%	0,00%	0,00%	0,00%	
21							
22	Deviation weights						
23	Below		5	1	1	1	
24	Above		0	0	0	0	
25							
26	Goal		0,018				

Figure 8: Implementation of MOMC model for 4 goal levels (second solution iteration)
(note: substitute decimal comma with decimal period)

In the second iteration, the program offered the following solution:

- **the most beneficial IT application is the application X_3** i.e. X_3=1, X_1= X_2= X_4= X_5= X_6= X_7=0;
- deviations from Quantity Benefits K^+ and K^- are 0% (goal level K=0.022);
- deviations from General Quality Benefits Op^+ and Op^- are 0% (goal level Op=0.074);
- deviations from Technological Quality Benefit T^- are 39.13% (goal level T=0.046);
- deviations from Risk Factors R^+ and R^- are 0% (goal level R=0.066);
- value of the Goal Function (minimum deviation sum) is 0.018.

For the decision maker, the first iteration of the problem solution is acceptable, according to which the best **application is X_2**, the value of the Goal Function is 0.004, and the negative deviation from the set priority for Quantity Benefits is 18.18%. This negative deviation is much lower than the negative deviation of **application X_3** of the set priority for Technical Qualitative Benefits (39.13% in the second solution iteration). The decision maker may continue with iterations of problem-solving solutions until he finds the optimal solution.

The advantage of using the model is in giving the option to the decision maker to implement a number of iterations in order to find the optimal IT option. The decision maker can also change goal levels, as well as weights of individual deviations.

4.3 IMPLEMENTATION OF GOAL LEVEL MODELS WHICH ENCOMPASS MORE COMPONENTS

In implementation of MOMC goal level models which encompass more components (9 criteria of the second level), the value of applications calculated by using the AHP method (Fig. 5), represent estimated values of each application for each benefits/risk category. They are described by variables $\mathbf{A_{ij}}$, $\mathbf{B_{ij}}$, $\mathbf{C_{ij}}$ and $\mathbf{D_{ij}}$. Since in this implementation the goal levels decompose into subordinate components, the following is true: $n_1=2$; $n_2=3$; $n_3=2$; $n_4=2$; index *i* changes value depending on the variables n_1, n_2, n_3 i n_4, and the index *j* changes values 1 to 7.

The following **goal levels** are set in this model:

Quantity Benefits (KVANT) includes two components ($n_1=2$):

1. increase of productivity (PROD); $K_1 = 0.014$
2. advancement of process (PROC); $K_2 = 0.010$

General Quality Benefits (OKVAL) includes three components ($n_2=3$):

1. improvement of decision-making process (ODL); $OK_1 = 0.020$
2. improvement of process management (UPR); $OK_2 = 0.045$
3. IT user satisfaction(KOR); $OK_3 = 0.016$

Technological Quality Benefits (TKVAL) includes two components ($n_3=2$):

1. possibility of simulation (SIM); $TK_1 = 0.008$
2. compatibility with environment (KOMP); $TK_2 = 0.025$

Risk Factor (RIZ) includes two components ($n_4=2$):

1. unrealised benefits (NK); $R_1 = 0.025$
2. additional expenses (education, late penalties) (TRO); $R_2 = 0.081$

Analogue to the MOMC model implementation for the 4 goal levels, acceptable deviations (positive deviations from set goal levels) are represented by values 0, and unacceptable deviations (negative deviations from set goal levels) by values greater than 0 (1-10).

$$\mathbf{PK_1^+ = PK_2^+ = POp_1^+ = POp_2^+ = POp_3^+ = PT_1^+ = PT_2^+ = PR_1^+ = PR_2^+ = 0}$$
$$\mathbf{PK_1^- = PK_2^- = POp_1^- = POp_2^- = POp_3^- = PT_1^- = PT_2^- = PR_1^- = PR_2^- = 1}$$

General Goal Function formula:

$$\text{Min}\ \left(\sum_{i=1}^{n1}(PK_i^+K_i^+ + PK_i^-K_i^-) + \sum_{i=1}^{n2}(POp_i^+Op_i^+ + POp_i^-Op_i^-) + \sum_{i=1}^{n3}(PT_i^+T_i^+ + PT_i^-T_i^-) + \sum_{i=1}^{n4}(PR_i^+R_i^+ + PR_i^-R_i^-)\right)$$

By inserting the values of deviation weights in the general formula, we reach the following form of the Goal Function:

Goal Function in case of goal levels which encompass more subordinate components

$$\text{Min}\ ((PK_1^-K_1^- + PK_2^-K_2^-) + (POp_1^-Op_1^- + POp_2^-Op_2^- + POp_3^-Op_3^-) + (PT_1^-T_1^- + PT_2^-T_2^-) + (PR_1^-R_1^- + PR_2^-R_2^-))$$

Limitations:

(1) $\sum_{j=1}^{n} A_{ij}X_j - K_i^+ + K_i^- = K_i$ **for** $i = 1,2,\ldots,n_1$

$$0.002X_1 + 0.007X_2 + 0.014X_3 + 0.002X_4 + 0.007X_5 + 0.014X_6 + 0.002X_7 - K_1^+ + K_1^- = 0.014$$

$$0.002X_1 + 0.010X_2 + 0.010X_3 + 0.003X_4 + 0.010X_5 + 0.010X_6 + 0.003X_7 - K_2^+ + K_2^- = 0.010$$

(2) $\sum_{j=1}^{n} B_{ij}X_j - Op_i^+ + Op_i^- = OK_i$ **for** $i = 1,2,\ldots,n_2$

$$0.008X_1 + 0.020X_2 + 0.008X_3 + 0.006X_4 + 0.020X_5 + 0.008X_6 + 0.004X_7 - Op_1^+ + Op_1^- = 0.020$$

$$0.008X_1 + 0.045X_2 + 0.045X_3 + 0.016X_4 + 0.045X_5 + 0.045X_6 + 0.016X_7 - Op_2^+ + Op_2^- = 0.045$$

$$0.003X_1 + 0.016X_2 + 0.016X_3 + 0.003X_4 + 0.016X_5 + 0.016X_6 + 0.003X_7 - Op_3^+ + Op_3^- = 0.016$$

(3) $\sum_{j=1}^{n} C_{ij}X_j - T_i^+ + T_i^- = TK_i$ **for** $i = 1,2,\ldots,n_3$

$$0.003X_1 + 0.008X_2 + 0.008X_3 + 0.003X_4 + 0.008X_5 + 0.008X_6 + 0.003X_7 - T_1^+ + T_1^- = 0.008$$

$$0.008X_1 + 0.025X_2 + 0.025X_3 + 0.008X_4 + 0.025X_5 + 0.025X_6 + 0.008X_7 - T_2^+ + T_2^- = 0.025$$

(4) $\sum_{j=1}^{n} D_{ij}X_j - R_i^+ + R_i^- = R_i$ **for** $i = 1,2,\ldots,n_4$

$$0.004X_1 + 0.025X_2 + 0.008X_3 + 0.008X_4 + 0.025X_5 + 0.008X_6 + 0.015X_7 - R_1^+ + R_1^- = 0.025$$

$$0.012X_1 + 0.041X_2 + 0.081X_3 + 0.014X_4 + 0.031X_5 + 0.066X_6 + 0.031X_7 - R_2^+ + R_2^- = 0.081$$

After defining the parameters and options, and after entering the values and formulae for the model of integer linear goal programming into the software tool, the program *solver* generates the optimal solution (Fig. 9).

Microsoft Excel - rad2

A27 = Goal

	A	B	C	D	E	F	G	H	I	J	K
1											
2			KVANT			OKVAL		TKVAL		RIZ	
3	Decision variables		PROD	PROC	ODL	UPR	KOR	SIM	KOMP	NK	TRO
4							Relative values (weights)				
5	X1	0	0,002	0,002	0,008	0,008	0,003	0,003	0,008	0,004	0,012
6	X2	1	0,007	0,010	0,020	0,045	0,016	0,008	0,025	0,025	0,041
7	X3	0	0,014	0,010	0,008	0,045	0,016	0,008	0,025	0,008	0,081
8	X4	0	0,002	0,003	0,006	0,016	0,003	0,003	0,008	0,008	0,014
9	X5	0	0,007	0,010	0,020	0,045	0,016	0,008	0,025	0,025	0,031
10	X6	0	0,014	0,010	0,008	0,045	0,016	0,008	0,025	0,008	0,066
11	X7	0	0,002	0,003	0,004	0,016	0,003	0,003	0,008	0,015	0,031
12	Sum	1									
13	Deviations										
14	Below		0,007	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,040
15	Above		0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
16	Limitation values		0,014	0,010	0,020	0,045	0,016	0,008	0,025	0,025	0,081
17	Goal levels		0,014	0,010	0,020	0,045	0,016	0,008	0,025	0,025	0,081
18											
19	Deviations (%)										
20	Below		50,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	49,38%
21	Above		0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
22											
23	Deviation weights										
24	Below		1	1	1	1	1	1	1	1	1
25	Above		0	0	0	0	0	0	0	0	0
26											
27	Goal		0,007								

Figure 9: Implementation of MOMC model for goal levels encompassing more components *(note: substitute decimal comma with decimal period)*

The results are as follows:

- **the most favourable IT application is application X_2** i.e. X_2=1, X_1= X_3= X_4= X_5= X_6= X_7=0;
- deviations from Quantity Benefits K_1^- (**increase of productivity-PROD**) are 50% (goal level K_1=0.014);
- deviation from Risk Factor R_2^- (**additional expenses of being late/education-TRO**) are 49.38% (goal level R_2=0.081);
- all other deviations (positive and negative) are 0%;
- the value of the Goal Function (minimum deviation sum) is 0.007.

Such negative deviations are not too acceptable to the decision maker, but are still the most favourable in comparison to the other IT applications. The decision maker may accept this solution as optimal or continue the implementation of the model (change goal levels or deviation weights), until he finds the most beneficial solution option.

Both implementations of the MOMC model (the model for 4 goal levels and the model for goal levels encompassing more components) show that the application IT2 (X_2) is the optimal solution in view of estimated investment benefits and risks, and the coordination with set goals.

5. CONCLUSION

Investments into IT have reached high figures and thereby motivated researchers and practicing scientists to assess the benefits of IT use. This, in turn, resulted in 25 years of development of models, methods and metrics using which one can test correlations between investing into IT and benefits which are gained by use of IT.

As has been stated, the estimation, assessment and evaluation of IT investments is a very complex task, since one need to assess not only the quantity factors, but also the quality and risk factors for which there exist no standardised metrics. A small number of organisations assess and evaluate the usefulness of IT, and if they do, they mostly use inadequate methods which do not encompass all necessary factors.

The goal of this paper was to solve the problem of decision-making in choosing the optimal IT investment by using a hybrid MOMC model, ands thus show this is, in fact, an acceptable model which incorporates all necessary factors into its assessment/evaluation (quantity, quality and risk factors). By using the AHP method, the decision maker may determine values (weights) of objective (quantity factors) and subjective criteria (quality and risk factors). In this way, all criteria can be quantified, and based on relative values, the MOMC model (*decision variables, the Goal Function, defined limitations*) generates the optimal solution. The model allows the decision maker the use of a greater number of iterations when solving the problem, as well as the possibility of changing the value(s) of certain variables, until the acceptable solution is reached.

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