Multi-criteria Selection of the Computer Configuration for Engineering Design

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Abstract: *The problems of choosing the PC configuration are Multi Criteria Decision Making (MCDM) problems. The paper presents an integrated approach to interdependent PC configuration selection problems using multiple criteria decision making methods and Delphi technique. Research has been based on the implementation of the concept of expert groups, extended approach to the Delphi method concept and appropriate statistical procedures and tools with software support. This provides the conditions for a decision maker, the manager, to connect all data and relations in one rational whole through multicriteria rating of alternative solutions; subsequently, by using appropriate methods of multicriteria decision making supported by software, the decision maker can find the solution for the optimisation problem-by the selection of the most favourable alternative with regard to the established criteria and appropriate preferences. The application of the proposed approach has been illustrated through an example of the selection of the best configuration of a computer system for simulation in engineering design in Serbian companies. The main contribution of the paper is presented methodological multicriteria approach that integrates the adequate methods and processes. The presented methodology opens the possibility for wide application in solving the problem of selecting computer configuration for different applications.*

Keywords: *Computer configurations, PROMETHEE method, delphi technique, information technology projects*

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1. Introduction

Dynamics and complexity of modern business and economy require adequate informing of managers on all hierarchy levels. Successfulness of managerial activities can very often depend on quality and good timing of available information on the basis of which a business decision must be made and proper activities undertaken. If there is no proper information, the potential decisions could have negative influence on company business. In order to make the decision making process efficient, the decision maker must have information on previous, ongoing and upcoming activities, events and conditions relevant for the problem in question. Previous experience, available information and knowledge are not always sufficient for solving single, specific and unstructured decision-making problems in organisations. Computer support contributes significantly to the successful problem solving. Its aim is to support the process of quality and timely decision-making.

Extremely fast development of information technologies has led to globalisation of the world market, strengthening of competition, connecting, fast information flow and creation of completely new products. All this has caused the change of daily circumstances in which managers make strategic, tactical and operative decisions. In dependence on management level, the levels of decision structure can be different, whereat the examples of structured, semi-structured and unstructured decisions can be found on all management levels.

The problems encountered by the strategic level managers are more often unstructured than the problems encountered by lower position managers. Higher hierarchy level of decision making implies less structured problems, smaller degree of precision and reliability of information, greater need for external and concise information and smaller need for internal and detailed data. It is obvious and understandable that the strategic decisions are the most difficult ones to make and decision-making is much easier on lower hierarchy levels. Executive information system, i.e., expert systems and decision-making support systems offer adequate assistance in solving unstructured problems at this level. Naturally, the input information is more precise on lower decision-making levels, which enables easier application of methods and techniques of multi-criteria decision-making. One of the methods for making this process more efficient is the application of information technologies and adequate computer support.

Information systems create values for the company by improving business process execution and enhancing decision making and strategic positioning [24]. Such systems can fundamentally change the way organizations do business and affect the entire organizational structure and components [12]. Risk associated with the use of information technology may adversely affect the performance of organizational members. Wide application of different models of decision making methodologies plays a significant role in risk assessment management [22].

One of the key issues in the acquisition and utilization of Enterprise Information Systems (EIS) is the determination of the value of investment in such systems. Faith and Uzoka [7] propose the adoption of a hybrid intelligent technique (fuzzy-expert system) in carrying out a cost benefit analysis of EIS investment. IT infrastructure investments include investments in connectivity, systems integration and data storage that may be used by multiple applications. Prior research has recognized the importance of a flexible IT infrastructure as a source of competitive advantage. Evidence regarding the value of IT infrastructures is anecdotal, and there is a realization that large investments in IT infrastructures are often difficult to justify. Kumar [11] expands on the idea that the value of an IT infrastructure depends on its use in an organizational context, and presents a relatively simple approach to understanding and assessing the value of IT infrastructure investments.

Researchers and practitioners alike have taken note of the potential value of an organization's IT infrastructure [16]. IT infrastructure expenditures account for over 58 percent of an organization's IT budget and the percentage is growing at 11 percent a year. Some even call IT infrastructure the new competitive weapon and see it as being crucial in developing a sustained competitive advantage. Unique characteristics of an IT infrastructure determine how valuable that infrastructure is for an organization. One of characteristics, IT infrastructure flexibility, has captured the attention of researchers and practitioners [3].

In order to select a suitable computer system for a specified job, several factors have to be considered [6]. Investment decisions for computer system are capital intensive and are usually made by a group of experts from different functional backgrounds within a company. Improper selection of computer technology may adversely affect the business of the company by reducing the productivity as well as profitability.

Problems of choosing the computer system, PC configuration, are Multi Criteria Decision Making (MCDM) problems. In this paper, we have suggested an integrated approach to interdependent PC configuration selection problems using multiple criteria decision making methods and delphi technique. The application of the proposed approach was illustrated through an example selection of the best configuration of a computer system for simulation in engineering design.

2. Materials and Methods

The development of IT technology also makes it possible to apply it in different ways. Nowadays, due to powerful user's tools, the final user is free from relying on ready-made software solutions to a large extent, which allows greater creativity in forming computer support which will satisfy his/her needs. The possibility for interactive automation of calculations contributes to different approaches in communication with the user. Computers application makes possible more efficient developing of new solutions, mainly due to packages for simulation of behaviour of newly developed technologies and products. Implementation of product simulation process is an important aspect of business improvement. In this sense, Pesonen *et al*. [17] introduce Product Process Decision Simulation (PPDS) as an approach to simulation solution of product development.

The designing process contains a series of operative, optimisation and information processes which generate the necessary information that completely defines the product. Application of computers for simulations in engineering designing implies several important aspects:

- Selection of proper computer system configuration;
- Selection of adequate programme support which should satisfy the actual application requirements;
- Adequate user's training which should provide conditions for efficient exploitation of available computer equipment.

The unavoidable elements of modern engineering designing are packages Computer Aided Design (CAD) and Computer Aided Engineering (CAE). By using CAD and CAE, the engineers design the product even before its production starts and they test its properties by proper computer simulations. There is a rapid progress in the automation of production processes due to the use of computer all the way through, from the design phase and production to final consumption, and most companies cannot follow the technological advances. Companies need to know which CAD/CAM packages are available and how to choose one that will help them gain a competitive advantage. Kannan and Vinay [9] present a multi-criteria approach for choosing the best or the most appropriate CAD/CAM packet out of four software packages for small manufacturing firms. Kharrat *et al*. [10] present a new interactive procedure for modelling engineering design problems. This procedure is based on the interactive goal-programming model and the concept of satisfaction functions that are used to elucidate and integrate the decision-makers preferences explicitly. Chiu and Yu [4] proposed a methodology for determining the material composition of the model based on the CAE analysis results. The issue of material composition selection is formulated as a MCDM problem. Methodology of multi-criteria optimisation can be applied in a wide range of selection of project alternatives [23]. Mahdavi *et al*. [24] point out the possibility of applying simulation-based decision support system in the improvement of production control. Application of Decision Analysis is also of great importance in the analysis of broad issues in management of information systems.

The application of adequate programme solutions for simulation in engineering designing implies the existence of appropriate hardware, i.e., adequate computer system configuration. Computing needs have increased and so have the needs for better processor technologies for computers. Computer prices decrease for a significant amount every 6 months, approximately. The PC technology is changing rapidly, and the increase of the speed of the Central Processing Units (CPUs) for PCs continues to double or even triple every year. In general, buying a PC configuration with the fastest CPU does not guarantee the optimal performance for specific applications. There is a great diversity of PC hardware components, such as the different types of CPUs, Random Access Memory (RAM) and the motherboards, and the limited compatibility between these components. Therefore, the PC configuration problems can actually be complex decision problems faced by many companies or individuals, with people always being interested in knowing the optimal PC configuration within budget limits. Given the diversity and limited compatibility for personal computer hardware, obtaining a sub-optimal configuration for different usages restricted to some budget limits and other possible criteria can be challenging. Tam and Ma [21] formulate the problem of choosing the PC configuration as a discrete optimisation problem, which considers the three different heuristic search strategies. The heuristic-based Micro-Genetic Algorithm (MGA) consistently outperformed the beam search and branch-and-bound method in most test cases. Dasgupta and Stoliartchouk [5] present a problem of choosing the appropriate hardware configuration in the form of tree structure, where nodes represent all possible hardware components of PC systems. After that, structured genetic algorithms are used to solve this multi-level optimisation problem.

Intensive technological development of hardware generates more and more new alternatives-configurations, which are actually realizable. The fact that they are different among each other, based on established criteria, creates certain difficulties in comparing and argumentative expressing of the preference for one alternative in relation to other ones without using adequate mathematical model. When it comes to complex business decisions and decision-making models, only when the very essence of the problem being solved is known, can the set of information needed for comprehensive and objective decision-making be defined.

The problem of choosing the PC configuration requires a multi-criteria model for an objective evaluation of designed solutions. Based on multi-criteria approach, it is possible to obtain arguments for emphasizing the advantages of one project alternative in relation to others. In this way, it is possible to perform inter-comparing of different alternatives per each established criterion, with the aim of obtaining the final range of total favourability. Preparation for decision-making implies previous gathering of information on relevant influential factors, their inter-connection and inter-dependence, finding of possibilities and, then, the generation of alternatives and formation of proposals for decision-making. After that, the possibilities for selecting the most favourable solution among many possible ones are created, which represents a multi-criteria ranking process.

Most organizational decision-making processes involve multi-criteria analysis, and fall within the realm of Multi-Criteria Decision Analysis (MCDA) [20]. MCDA situations are structured, semi-structured or unstructured, and a huge problem arises where there is a high level of variance in parameter structure. The multi-criteria decision aid method provides the decision maker with tools that enable problem solving by taking into consideration different points of view, which are sometimes contradictory [27]. Sevastjanov and Figat [19] state that there are different definitions of MCDM in the literature, but the two pivotal problems are how to evaluate alternatives and how to compare them, according to the type of MCDM task intended for solving (choice, ranking, sorting, etc.,). Many studies have been published on MCDM methods and application of optimization methods in different areas [25].

On the whole, the problem of multi-criteria decision-making comes down to a task of determining the final rank of alternative solutions, estimated in various criteria systems by using appropriate methods. By using methods for multi-criteria ranking, a clear idea on total favourability of one alternative compared with other ones can be obtained, which provides the decision-maker with more arguments for explaining his/her decision. When selecting the considered alternatives the main problem is the defining of multi-criteria base for decision-making, i.e., the problem is how to use as small number of criteria as possible for expressing all complexity and comprehensiveness of the analysed problem.

A complex procedure of multi-criteria decision-making includes alternatives defining, criteria system, determining of relative significance, results analysis, and multi-criteria ranking. This paper presents an example of the selection of the most favourable computer configuration for engineering design for the needs of the technological preparation of production in the cutting tools manufacturing under specific conditions in Serbia in 2012.

Nowadays, the requirements are multicriterial and they should express the comprehensiveness and complexity of the problem of ranking when selecting the most favourable alternative. The decision maker's task is to select the alternative, computer system configuration, which can satisfy the actual needs and purpose-the computer simulation in engineering designing. Based on available information, eight potential alternatives-computer system configurations-were selected.

The process of multi-criteria ranking of the estimated alternatives was realised by application of promethee method. The method promethee [1, 2, 15] introduces preferences nonlinearity and offers more possibilities for expressing subjective preferences-by selection of the preference functions type and parameters values. The used PROMETHEE method is based on additive value functions [18].

The defining of the system of criteria and alternatives that will enter the multi-criteria base for decision-making was performed with the aim of selecting the computer system configuration that is most favourable for the actual needs of computer simulation in engineering designing. In addition, the defining of the structure of decision-makers preferences was carried out as well, by determining relative significance of the criteria and selecting the appropriate preferential functions and necessary parameters.

3. Results and Discussion

Defining of the system of criteria and determining of their relative significance was made by application of Delphi method [13, 26], by inviting the selected individuals, experts, to give their opinion on the actual problem, i.e. to propose criteria, give estimation and certain comments based on their knowledge and experience. Delphi is a popular, long-range, qualitative forecasting technique that has been extensively applied to a wide variety of problems in different domains. Research studies [8] have shown that the application of Delphi method is convenient for areas with lack of empiric data, such as determining relative significance of criteria according to which the most favourable alternative solution at MCDM is selected. Criteria aggregation was made based on estimates of a narrow expert group, with the aim of determining criteria that could indicate, comprehensively and objectively, the convenience of applying a particular computer system configuration for the needs of computer simulation in engineering designing.

Since all the complexity, comprehensiveness and diversity of this problem must be expressed with as fewer criteria as possible, 7 following criteria were selected, Table 1.

Table 1. Criteria system.

No.	f_i	Criteria	Unit	Max/min
1.	f_1	Processor speed	GHz	max
2.	f_2	Cache memory	Mb	max
3.	f_3	Operating memory	Gb	max
4.	f_4	HDD capacity	Gb	max
5.	f_5	Graphics subsystem	Gb	max
6.	f_6	Processor bus / Front-side bus (FSB)	MHz	max
7.	f_7	Price	$	min

The selected criteria express different requirements; they are given in different units, with prominent requirement for maximization of the first 6 criteria and minimization of the 7th criterion.

Each Delphi process participant should state his/her preferences for each of the selected criteria according to which the selection of computer configuration system would be made. Stating of preferences implies defining of the relative significance for each of the criteria, so that the total sum of all values, per all criteria, is 1, i.e., 100%, when shown in percentages. Delphi method was realised in three rounds, with the participation of 9 experts from this area (E1, E2, ...E9), selected by expert group. Communication with each participant was realized by e-mail, so that they remained anonymous until the investigation completion.

In the first round of delphi process, the participants were informed on the problem and objective of investigation, and on method of the process realization. Each participant received, by email, a questionnaire 1, which contained a list of the selected criteria for the evaluation of the computer system configuration, as well as the instructions for the realisation of the process. After receiving the replies of all the first round participants, replies processing was performed. Processing of the results was done in MS Excel and it implied the calculation of the mean value, standard deviations and variation coefficient for each of the criteria. The results of the 1 round of delphi process are shown in Table 2.

Table 2. Results of the 1 round of Delphi process.

Criterion		E1	E2	E3	E4	E5	E6	E7	E8	E9	Arithmetic mean	Standard deviation	Coefficient of variation
f_i	Name												%
f_1	Processor speed	0.35	0.30	0.25	0.22	0.25	0.18	0.20	0.30	0.20	0.25	0.054	21
f_2	Cache memory	0.10	0.10	0.15	0.15	0.15	0.14	0.15	0.10	0.15	0.13	0.023	17
f_3	Operating memory	0.15	0.20	0.20	0.30	0.15	0.16	0.15	0.20	0.15	0.18	0.046	25
f_4	HDD capacity	0.15	0.10	0.10	0.10	0.20	0.10	0.10	0.15	0.10	0.12	0.034	28
f_5	Graphics sub-system	0.05	0.05	0.10	0.05	0.05	0.10	0.10	0.05	0.10	0.07	0.025	34
f_6	Processor bus (FSB)	0.10	0.15	0.05	0.08	0.10	0.10	0.10	0.05	0.05	0.09	0.031	36
f_7	Price	0.10	0.10	0.15	0.10	0.10	0.22	0.20	0.15	0.25	0.15	0.055	36
Σ		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-

In the second round of Delphi process, each of the participants was sent a questionnaire 2 which contained the results of the previous round. Taking into consideration the results obtained in the 1 round, in the 2 round the experts had the possibility to express their agreement with each of the replies, with the possibility to change their estimation regarding group reply and carry out proper regrouping. By merging and processing the results shown in Table 3, after the 2 round, it was determined that there were no major deviations in mean values of each criterion weight; therefore, these values were adopted as relative criteria significance and were shown in Table 4.

Table 3. Results of 2 round of Delphi process.

Criterion		E1	E2	E3	E4	E5	E6	E7	E8	E9	Arithmetic mean	Standard deviation	Coefficient of variation
f_i	Name												%
f_1	Processor Speed	0.30	0.25	0.25	0.22	0.25	0.18	0.20	0.30	0.20	0.24	0.040	17
f_2	Cache memory	0.10	0.15	0.15	0.15	0.10	0.14	0.15	0.10	0.10	0.13	0.024	19
f_3	Operating memory	0.15	0.20	0.15	0.20	0.15	0.16	0.15	0.15	0.15	0.16	0.020	13
f_4	HDD capacity	0.15	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.11	0.021	19
f_5	Graphics sub-system	0.05	0.05	0.10	0.05	0.10	0.10	0.10	0.05	0.10	0.08	0.025	32
f_6	Processor bus (FSB)	0.10	0.10	0.10	0.08	0.10	0.10	0.10	0.15	0.10	0.10	0.018	17
f_7	Price	0.15	0.15	0.15	0.20	0.15	0.22	0.20	0.15	0.25	0.18	0.036	20
Σ		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-

Table 4. Multi-criteria base for decision-making.

Criterion			Alternative							
f_i	Max/ min	Relative importance	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
f_1	max	0.24	3.30	3.50	3.30	3.90	3.10	3.00	3.40	3.50
f_2	max	0.13	3	3	6	8	6	3	6	6
f_3	max	0.16	4	8	8	16	6	8	8	8
f_4	max	0.11	1000	1500	1500	1000	2000	500	1000	1500
f_5	max	0.08	1	2	2	2	1	1	2	1
f_6	max	0.10	1333	1600	1333	2133	1333	1333	1600	1600
f_7	min	0.18	520	740	700	1420	670	430	970	720

By analysis of the obtained results, it was determined that the variability level which satisfies the needs of the estimated problem was accomplished, i.e. the appropriate and acceptable consensus level was obtained, by which the process was completed, and each of the participants got final results, shown in Figure 1.

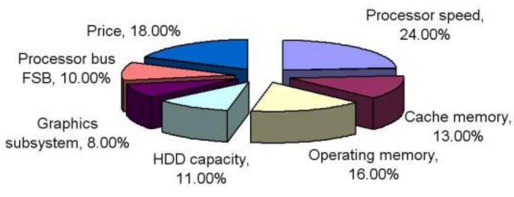

Figure 1. Relative importance of criteria.

The consistency in the experts' attitudes provided a high level of agreement in determining relative significance of the criteria. The participants' opinions were not influenced by meeting "face to face" or by group pressure and the fact that they remained mutually anonymous made it possible for them to express their preferences without the influence of others.

In the process of forming the system of criteria and estimating their relative significance, the application of the extended approach to delphi method concept created conditions for improving the quality of designing multi-criteria base for decision-making. Joint expert prognosis of criteria weight quantification was obtained by methodologically defined, organised, and systematised adjustment of individual estimations, with application of procedure of statistical processing of those prognoses with computer support.

4. Multi Criteria Ranking

By defining potential alternatives and the system of criteria for their estimation, designing of multi-criteria base was performed (Table 4). Specific data for specific conditions of industrial production of cutting tools in Serbia in 2012 are given. The designed multi-criteria base represents a foundation for continuation of the multi-criteria ranking process by application of PROMETHEE method, with proper support of developed software solution OptiPROM.

The software OptiPROM represents a decision-maker's support in solving various problems of multi-criteria decision-making by applying PROMETHEE method. Although it is primarily intended for multi-criteria ranking on the basis of a new type of preference function, OptiPROM programme also provides opportunities for choosing one of 6 known generalized preference functions in order to disclose preferences under certain criteria, with relevant values of parameters.

The estimated application implies already defined criteria and alternatives that will enter multi-criteria base for decision-making. The user selects appropriate preferential functions and enters necessary parameters, which implies that the user-decision-maker must have proper experience in application of these methods.

Gauss' criterion, with calculated standard deviation values, was added to each of the estimated criteria, except for the fifth (f_5), for which a usual criterion has been selected. Based on alternatives values distribution per each of the criteria, the software performed calculation of the parameter σ for each estimated criterion as shown in Figure 2.

Statistics

	f1	f2	f3	f4	f5	f6	f7
Minimum	3.000	3.000	4.000	500.000	1.000	1333.000	430.000
Maximum	3.900	8.000	16.000	2000.000	2.000	2133.000	1420.000
Arithmetic Mean	3.375	5.125	8.250	1250.000	1.500	1533.125	771.250
Standard Deviation	0.259	1.763	3.231	433.013	0.500	258.231	286.986

Exit

Figure 2. Statistics criteria.

Values obtained in such a way, for each criterion, show to what extent particular values deviate from mean value, on average. In this way, particular preferences are expressed per criteria and conditions are made for application of PROMETHEE method.

The application of software OptiProm has a significant advantage in the sense that it offers a possibility for changing preference parameters (p, q, σ, a, b), preferential functions themselves as well as relative significance of the criteria. By such approach, the programme offers broad possibilities for simulating various situations in relation to planned ones and provides the evaluation of their influence on the results, i.e., increase of total efficiency of decision-making process.

After completed defining of multi-criteria base size, the following elements are defined for each criterion in the window "Criteria": name, relative significance, preferential function type, necessary parameters, extremization type, as shown in Figure 3.

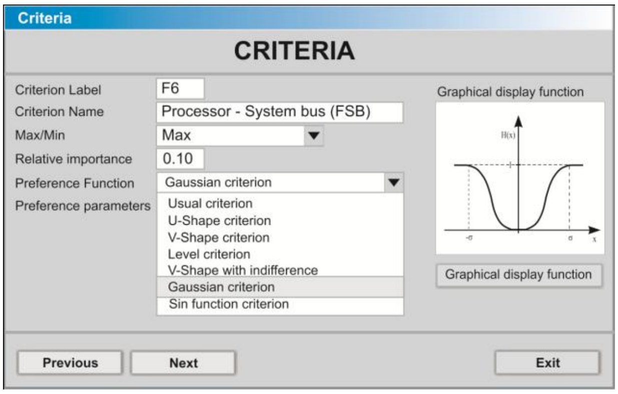

Figure 3. Defining parameters for criteria.

By selecting preferential function and defining necessary parameters for each of the criteria, it is possible to see graphic presentation of the selected preferential function on the screen, with actual parameter values.

Software OptiPROM enables direct entering of values into multi-criteria base, i.e., display of entered alternatives values per each criterion within a separate window. After all the necessary values are entered, software OptiPROM performs the necessary calculations automatically, as requested by PROMETHEE method concept. Thereat, there is a possibility for displaying the values of preference index on the screen for each couple of alternatives, i.e., the values of incoming, outgoing and net flow for each of considered alternatives as shown in Figure 4.

Outranking flows

VALUES OF INCOMING, OUTGOING AND NET FLOW

	a1	a2	a3	a4	a5	a6	a7	a8
Incoming flow	0.499	1.732	1.530	4.223	1.197	0.720	1.547	1.721
Outgoing flow	2.903	1.120	0.953	1.435	1.731	2.745	1.326	0.958
Net flow	-2.404	0.613	0.577	2.788	-0.534	-2.025	0.222	0.763

Preference indices Exit

Figure 4. Values of incoming, outgoing and net flow

Based on obtained values, by applying PROMETHEE II method, the programme gives complete order of estimated alternatives, in window frame "Ranking" as shown in Figure 5.

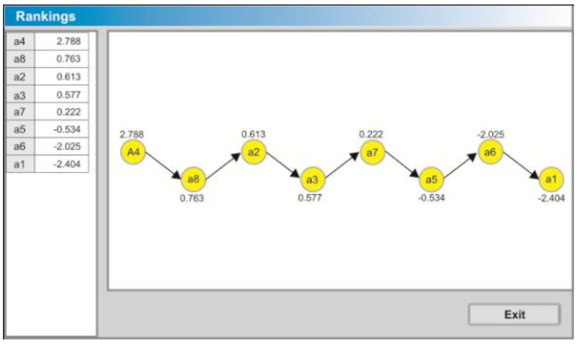

Figure 5. Rank of compared alternatives.

By multi-criteria ranking of estimated alternatives, the advantage of alternative a4 is emphasised in relation to other compared alternatives, i.e., Configuration 4 is selected as the optimal one.

5. Conclusions

Intensive technological development of hardware generates more and more new alternatives-configurations, which are actually realizable. The fact that they are different among each other, based on established criteria, creates certain difficulties in comparing and argumentative expressing of the preference for one alternative in relation to other ones without using adequate mathematical model. Nowadays, the requirements are multicriterial and they should express the comprehensiveness and complexity of the problem of ranking when selecting the most favourable alternative. The decision maker's task is to select the alternative, computer system configuration, which can satisfy the actual needs and purpose-the computer simulation in engineering designing. Based on available information, eight potential alternatives-computer system configurations -were selected.

Problems of choosing the PC configuration are Multi-Criteria Decision Making problems. In this paper, we have suggested an integrated approach to interdependent PC configuration selection problems using Multiple Criteria Decision Making methods and Delphi technique. When forming the system of criteria and estimating their relative significance, the application of the extended approach to Delphi method concept creates conditions for improving the quality of designing multi-criteria base for decision-making. Joint expert prognosis of criteria weight quantification was obtained by methodologically defined, organised, and systematised adjustment of individual estimations, with application of procedure of statistical processing of those prognoses with computer support.

By using the proposed approach in solving various problems of multi-criteria decision-making, a clear idea on total favourability of one alternative compared with other ones can be obtained, which provides the decision-maker with more arguments for explaining his/her decision regarding the advantage of the selected alternative.

In this way, a decision-maker can connect all the data and relations at multi-criteria selection of alternative solutions into one rational totality, and then, by using software developed for that purpose he/she can reach the optimisation problem solution-selection of the most favourable alternative – relatively easily, and all that in the sense of established criteria and appropriate preferences.

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