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A. V. PETUKHOV

FORMALIZATION OF THE PROBLEM OF SELECTION OF AUTOMATED SYSTEM

Sukhoi State Technical University of Gomel, Gomel, Republic of Belarus

The results of many years of research in the field of formalizing the task of selecting automated systems for various areas of design and office activities are given. The purpose of the study is the development of methods for qualitative and quantitative evaluation when choosing an automated system, taking into accounts the operating conditions and customer requirements. Qualitative assessment is based on the theory of choice and decision making, which examines the mathematical models of this type of activity. In view of the fact that in the problem under consideration, many alternatives, which are automated systems, are known, it can be related to the choice problem. The peculiarity of this approach is that it does not require a complete restoration of the principle of optimality, but allows us to confine ourselves to information sufficient to identify the optimal variant. The quantitative assessment is based on the determination of the projected annual economic effect from the introduction of an automated system. The described technique can be used by enterprises and organizations in the evaluation of automated systems at the stage preceding the tender for their purchase.

Keywords: choice *of automated system, qualitative assessment, quantitative assessment, theory of choice and decision-making*

Introduction

Expanding the use of information technology in practically all spheres of life of modern society and the continuous appearance of various automated systems (AS) on the market actualizes the task of developing a methodology for assessing the optimal version of a particular system, based on operating conditions and customer requirements.

As a rule, enterprises, institutions and firms especially need the proposed methodology in two cases:

1) The enterprise has only been established and needs to purchase AS for work;

2) The enterprise already exists for a while, has accumulated certain experience in the use of information technology, but the existing situation does not suit management and modernization is required, including the purchase of new software.

In both cases, experience shows that the evaluation methodology must meet two basic requirements.

First, the methodology should be as broad and objective as possible, based on simple and understandable criteria that do not allow double interpretation, equally perceived by both customers and performers.

Secondly, the methodology should allow the implementation of the evaluation procedure on the basis of a widespread computer program, for example, Microsoft Excel. This will ensure the simplicity of creation, the adequacy of perception and ease of modernization. This is explained by the fact that the customer, in most cases, does not have the necessary level of knowledge in the field of existing decision support technologies and therefore does not want to risk losing money, trusting, in his opinion, a complex and biased program.

The formalization of the task of selecting an AS involves a comprehensive study of systems, including qualitative and quantitative assessments.

1. The method of qualitative evaluation of AS

The basis for the methodology of qualitative assessment is the theory of choice and decision-making, which examines the mathematical models of this type of activity.

Let there be a lot of AS, and the problem is to isolate a subset from it based on the idea of the quality of the options, characterized by the principle of optimality. In this case, the decision-making task is called a pair <Ω, *OP*>, where Ω – many options, *OP* – optimality principle. By the solution of the problem <Ω, *OP*> we mean the set $\Omega_{OP} \subseteq \Omega$, obtained with the help of the optimality principle *OP*.

The mathematical function of the *OP* optimality principle is the C_{OP} selection function. It associates with any subset $X \subseteq \Omega$ its part $C_{OP}(X)$. The solution Ω_{OP} of the original problem is the set $C_{OP}(\Omega)$.

The decision-making tasks are distinguished depending on the available information on the set Ω and the optimality principle of the *OP*. In view of the fact that in the problem under consideration, the set of alternatives that are AS is known, it can be related to the choice problem. Thus, the problem of choice is a special case of the general problem of decision-making. The peculiarity of this approach to the solution of the problem of choice lies in the fact that in the general case it does not require a complete restoration of the optimality principle, but allows us to confine ourselves only to information sufficient for distinguishing Ω_{OP}. The general optimization problem may not assume the maximization of one or more numerical functions. Its meaning is to select the set of the best elements, i. e. in calculating the value of $C_{OP}(\Omega)$ for given Ω and C_{OP}. If C_{OP} is a scalar selection function on the set Ω, then we get the usual optimization problem.

The alternatives in question have many properties that affect the solution. Being enlarged these properties can be classified into specific sets. In particular, when solving the problem of choosing a computer-aided manufacturing (CAM) system, the following sets of properties are considered: M' – integration with CAD systems; M'' – design of technological processes; M''' – work with technology directories; M'''' – calculation of allowances and cutting modes; M''''' – material and technical rationing.

Detailing of the indicated sets, shows that each of them is formed by several properties. For example, $M'\{m_1', m_2'\}$, where m_1' – data transfer on the composition of the machine-building product; m_2' – data transfer of the elements of machine parts.

Similarly, $M''\{m_1'', m_2'', m_3''\}$, where m_1'' – interactive designing of technological processes on the basis of code information entered into the computer-aided process planning (CAPP) system; m_2'' – interactive designing of technological processes on the basis of code information transmitted automatically from the CAD-system file to the CAPP system; m_2''' – automatic design of technological processes on the basis of the code information transferred from a file of CAD-system in the CAPP system.

Some of these properties are expressed by a number. This is confirmed by the existence of a mapping $\varphi:\Omega \to E_1$. Consequently, the savings from reducing the labor intensity of work in the CAM system is a criterion in the problem under consideration, and the number $\varphi(x)$ is the estimation of the alternative x by the criterion. Simultaneous accounting of individual properties can be difficult. In this case, the groups of properties that aggregate in the form of aspects are distinguished. An aspect is a complex property of alternatives, which simultaneously takes into account all the properties that belong to the corresponding group. In a particular case, an aspect can be a criterion. For example, when considering the properties that make up the set M', the economy can be used as a criterion when implementing a CAM system integrated with the CAD system.

Therefore, all the properties $m_1', m_2'', ..., m_n'''$, which are taken into account when solving the problem <Ω, *OP*>, are criteria. We put in correspondence to the criterion m_j the j-th axis of $E_n\,(j=\overline{1,n})$. We map the set Ω в E_n, associating with each alternative $x \in \Omega$ the point $\varphi(x) = \{\varphi_1(x), ..., \varphi_n(x)\} \in E_n$, where $\varphi_j(x)$ – is the estimate of x by the criterion $m_j\,(j=\overline{1,n})$. A criterion space is a space whose coordinates of points are considered as estimates by the corresponding criteria.

The calculation of the estimates $\varphi_j(x)$ of each Ω_j-th alternative over the whole set of properties allows us to determine the indicator of the overall efficiency $E_{\Omega j}M_i$. To do this, it is necessary to classify the estimates according to the properties that are to be maximized and minimized.

The purpose of this classification is that, in calculating the indicator of the overall efficiency $E_{\Omega j}M_i$, it is correct (in the sense of the sign) to take into account the values of the efficiency measures for the properties to be minimized.

Indeed, based on the physical meaning of this classification, it is desirable that estimates for the properties subjected to minimization of $\varphi_j^{(min)}(x)$ be minimal (for example, costs associated with the purchase of computer facilities), but on properties subjected to maximization $\varphi_j^{(max)}(x)$ are maximal.

In this case, the calculation of the indicator of the overall efficiency $E_{\Omega j}M_i$ of the Ω_j-th projection alternative is made by the formula

$$E_{\Omega_j} M_i = \sum_M \varphi_j^{(\max)} M_i - \sum_M \varphi_j^{(\min)} M_i$$

where $\sum_M \varphi_j^{(\max)} M_i$, $\sum_M \varphi_j^{(\min)} M_i$ – accordingly, the sum of measures of efficiency on the properties subject to maximization and minimization.

After these calculations, confidence intervals of the indicator $E_{\Omega j}M_i$ are determined.

The final stage of the choice of the CAPP system is the decision-making based on the analysis of the calculated estimates $\varphi_j(x)$ and the indicator of the overall efficiency $E_{\Omega j}M_i$.

The alternative having the largest value of the indicator of the overall efficiency $E_{\Omega j}M_i$, can be considered as optimal for the considered set of alternatives of the CAPP systems Ω. Therefore, if the indicator of the overall efficiency $E_{\Omega j}M_i$ of the alternative to the CAPP system is the largest in magnitude, taking into account the sign on the whole set of design alternatives, then the Ω_j-th alternative is optimal.

However, it is quite logical to take step by step decisions.

1. An alternative with the highest overall efficiency index max $E_{\Omega j}M_i$ is adopted as a nodal alternative.

2. Analyzing the estimates $\varphi_j(x)$ of each alternative for all purposes, an ordered set of alternatives Ω in accordance with the values $\varphi_j(x)$ is constructed.

3. In each order of importance, the set of estimates $\alpha_i = \{\varphi_1(x), ..., \varphi_n(x)\}$ determines the place of the nodal alternative to the design of Ω_{nod} and determines the ways of its optimization:

A) if the set α_i is constructed for the goal that is to be maximized, then Ω_{nod} can be optimized by the alternatives to the left of it in the set Ω;

B) if the set α_i is constructed for a goal subjected to minimization, then Ω_{nod} can be optimized by the alternatives to the right of it in the set Ω.

In this case, possible ways of optimizing the nodal alternative Ω_{nod} are determined. The possibility of their practical implementation is considered in the subsequent stages of engineering analysis and is related to the resolution of compatibility and feasibility problems. In particular, when solving the problem of choosing the CAPP system, the ways of optimizing the nodal alternative can be scheduled at the stage of the tender for the purchase of the above-mentioned system.

2. The method of quantification evaluation of AS

The annual economic effect from the introduction of an AS is determined by the formula

$$Y_{\text{econ}} = \sum_{i=1}^{i=k} Zp_i - \sum_{j=1}^{j=m} Zt_j \qquad (1)$$

where $\sum_{i=1}^{i=k} Zp_i$ – the amount of saving wages of workers in the i-th categories due to the increase in labor productivity when implementing an AS for one year of work; $\sum_{j=1}^{j=m} Zt_j$ – amount of costs for the implementation of an AS for j-th items of expenditure.

The amount of saving wages of workers in the i-th categories due to the increase in labor productivity when implementing an AS for one year of work is determined by the formula

$$\sum_{i=1}^{i=k} Zp_i = \sum_{i=1}^{i=k} \left(Zp_i^Y n_i \right) \qquad (2)$$

where Zp_i^Y – the amount of saving on the wages of one specialist of a certain category, resulting from a reduction in labor intensity by the types of work performed, for one year of work; n_i – number of specialists in the i-th categories of employees.

The amount of costs for the implementation of an AS for j-th items of expenditure is determined by the formula

$$\sum_{j=1}^{j=m} Zt_j = \sum_{j=1}^{j=m} \left(St_j^{emp} \times \sum_{j=1}^{j=k} n_j \right) + \sum_{j=1}^{j=p} St_j^{soft} \qquad (3)$$

where St_j^{emp} – the cost of one user license by user category; n_j – number of specialists in the j-th categories of employees; $\sum_{j=1}^{j=p} St_j^{soft}$ – sum of the cost of j-th work on the implementation of an AS.

3. The results of approbation of the described approach

Approbation of the described technique was carried out for a long time in solving problems of the choice of AS.

In the beginning, it was used to identify the most important functions and tasks in the formation of ways to create CAM systems of prototypes for forage harvesting equipment [1], [2]. The obtained results were used in the Main specialized design bureau for the complex of forage harvesting machines when creating the first stage of the CAM system. Implemented on the basis of SM-1420 computer, the CAM system consisted of CAPP system of prototypes of forage harvesting equipment [3] and an AS for structural analysis of prototype designs [4].

Later on, when switching to PC and integrating the above mentioned system, the methodology was used to select the path of their further development. In particular, with its help, the decision was made to model decision making when choosing methods for automating the technological preparation of production of prototypes for forage harvesting and grain harvesting equipment [5]. In addition, the technique was used for the information analysis of the technological preparation for the production of prototypes for forage harvesting and grain harvesting equipment [6], and also for the development of the sequence of the creation of integrated systems [7].

To expand the scope of the described methodology, it was tested while analyzing and developing the proposals for the modernization of the existing PDM system of the joint stock company «Gomeltransneft Druzhba» [8].

In 2013, the methodology was used in higher education. Namely, when choosing a CAPP system for the performance of laboratory work at the Sukhoi State Technical University of Gomel [9].

Conclusion

The described technique can be used by enterprises and organizations in the evaluation of AS at the stage preceding the tender for their purchase. One of the advantages of the methodology is that it is based on simple and understandable criteria that do not allow double interpretation, is equally perceived by both customers and executors, and also allows the implementation of the evaluation procedure based on the Microsoft Excel office application. This circumstance ensures the ease of creation, adequacy of perception and ease of modernization at the request of the decision-maker.

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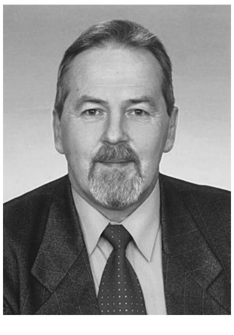
А. В. Петухов

ФОРМАЛИЗАЦИЯ ЗАДАЧИ ВЫБОРА АВТОМАТИЗИРОВАННОЙ СИСТЕМЫ

Учреждение образования «Гомельский государственный технический университет имени П. О. Сухого», г. Гомель, Республика Беларусь

В статье приводятся результаты многолетних исследований в области формализации задачи выбора автоматизированных систем для различных сфер проектировочной и офисной деятельности. Цель исследования заключалась в разработке методик качественной и количественной оценки при выборе автоматизированной системы, исходя из условий эксплуатации и требований заказчика. В основу методики качественной оценки положена теория выбора и принятия решений, которая исследует математические модели этого вида деятельности. Ввиду того, что в рассматриваемой задаче множество альтернатив, которыми являются автоматизированные системы известно, она может быть отнесена к задаче выбора. Особенность такого подхода состоит в том, что он не требует полного восстановления принципа оптимальности, а позволяет ограничиться информацией, достаточной для выделения оптимального варианта. Количественная оценка базируется на определении прогнозируемого годового экономического эффекта от внедрения автоматизированной системы. Описанная методика может использоваться предприятиями и организациями при оценке автоматизированных систем на стадии, предшествующей проведению тендера на их закупку.

Ключевые слова: *выбор автоматизированной системы, качественная оценка, количественная оценка, теория выбора и принятия решений*



Петухов Александр Владимирович – старший преподаватель кафедры «Технология машиностроения» учреждения образования «Гомельский государственный технический университет имени П. О. Сухого»

Alexander Petukhov – Senior lecturer of the chair «Technology of mechanical engineering» of the Sukhoi State Technical University of Gomel.

E-mail: Petukhov@tut.by/