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THE PROBLEM OF CHOOSING NEW TECHNOLOGIES UNDER FUZZY-DATA CONDITIONS

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RESUMEN:

The choice and introduction of new technologies in enterprises with the established production base require all-round assessment of the expected results. It is obvious that a change of the technology should raise the quality of products. This comprehensive indicator,including numerical and descriptive assessment of consumers' properties of products, can be considered as a vector function of aim in an optimization problem of choosing the best technology. Restrictions in such a problem result from the assessment of various economic, social, ecological and other factors that describe each technology. For example, such factors can be: all-round expenses for the modernization of production, expenses for the possible supply of new raw-materials, the influence of the technology on the environment, expenses due to to the possible release and re-training of the personnel, etc. The majority of indicators and factors that the problem comprises can be assessed only as fuzzy-data (numbers, confidence intervals, sets). It is suggested to base mathematical methods for comparing technologies under such an approach on the introduction of binary relation of equivalence and clustering of sets of technologies.

KEYWORDS: Fuzzy sets. Optimization problems.

THE PROBLEM OF CHOOSING NEW TECHNOLOGIES

The basic factor of effective functioning of any enterprise under market economy is the necessity to carry out rather often the improvement of consumer goods and even the transfer to the production of new ones. Clearly the problem amounts to constant comparison and assessment of the associated technologies that exist in the information base. The problem of choosing a technology substantially becomes more complicated due to the desire to reduce costs during its implementation at the expense of maximum possible use of the existing equipment and personnel's qualifications, the established relations, raw materials provision and other conditions typical for the production base.

Following are discussions of possible formalization of the problem under consideration using construction of a mathematical model of decision-making and choice of methods providing solution close to the best one. As a preliminary we define in a more precise way some initial notions and conditions of formalization.

Production process can be described in terms of relations between basic elements of material and production system, i.e. performers in the sphere of production, technical means, input and output products. These relations are technological operations. A technological operation is a mechanical or physical and chemical effect on products or their conversion. A set of technological operations performed on particular equipment forms a technological process. A set of technological processes and the required organization structures and information flows for output of products of the same type we define as a technology. For the problem under consideration in compliance with the necessity to save and use the existing production base it is also necessary to consider technology structure. The following premises and notions may serve as initial ones. Technological operations of conversion (processing), transportation and storage are distinguished. Processing operations are related to changes of mechanical or physical and chemical properties of the initial product. Operations of transportation and storage change the position of the initial product in reference to space and time. Each operation can be represented as production links that perform certain technological operations. These links can be machine tools, pilot stands, transportation facilities, warehouses, etc. Production process is related to the advancement of the product via links in the direction from input to output. Movement of the product is assessed by time spent for carrying out the operation. Thus, this material flow can be characterized by capacity, i.e. the number of flow units per time at the input and output of the production link. In parallel with the material flow there exists an information flow, in a broad sense, that provides changes in the state of processing and transportation links (switch in operations) and storage ones (change in quantity of stored products).

Irrespective of the variety of technological processes and technologies providing output of products in respect to users of such technologies there is a set of indicators (parameters) that characterize the results of operation of such technologies. Groups of such parameters can be, for example, requirements to the quality of products, assessments of ecological consequences when realizing the technology, requirements to the personnel, mix of plant including probable expenses for retraining, restrictions on resources, etc. An ordered set of such parameters will be called a vector-characteristic of the technology necessary for the user and will be indicated by $\mathbf{T_0}$.

It is important that dimensions and composition of parameters of $\mathbf{T_0}$ vector can be a dynamical value changing in relation to the request from the customer. In the course of time and with the deeper understanding of the problem these indicators $\mathbf{T_0}$ may change and these changes should have no effect on decision-making procedure. For example, at the first stage of choice the user can describe only groups of parameters characterizing productivity and the desired quality of the product. At some successive stages of choice when there is a need to use the available equipment $\mathbf{T_0}$ vector should be extended by including a group of parameters typical for the structure of the technology with respect to definite production links. Only such an approach to form $\mathbf{T_0}$ vector meets user's requirements and ensures simplicity of taking into account real conditions of introduction of the technology.

Let us suppose that in the information base of technologies there is n technologies to manufacture the product. There are not standards to describe technologies in data bases. It is important to have a possibility to extract (calculate) or assess expertly from the diverse descriptions the information regarding values of the parameters as in T0 vector and by this means to form vectors $\mathbf{T_1}, ..., \mathbf{T_n}$. Thus, the problem of choosing a technology amounts to the problem of selection from a set of $\mathbf{T_1}, ..., \mathbf{T_n}$ vectors the most closely related one to $\mathbf{T_0}$ vector.

Generally speaking in actual practice the number of n available technologies is not too great and at first glance the problem of comparing $\mathbf{T_0}$ vector with each one from $\mathbf{T_i}$ (i=1..n) is simple and is not labour-consuming. But a number of peculiarities of all these vectors-characteristics leads to the necessity to study this problem as a general decision-making problem.

Among such peculiarities first of all it is essential to single out the fact that components of vectors may have different degree of "remoteness" from indeterminancy, i.e. some components are measurable parameters that are either concrete numbers or can be specified as interval assessments, other ones are parameters the probabilities of certain values of which are defined and the law of their distribution is determined. Third group of components comprises diffuse data certain values of which are defined by functions of belonging to the universum, and finally there are linguistic parameters values of which are specified only as gradations of a certain quality.

It is worth noting that although the user has a particular system of preferences based on his experience, i.e. knowledge regarding the importance of some parameters as compared with other ones, this system, as a rule, specifies a partial order on a set, and often only on a subset of parameters and does not lead to the solution rule as is the convention when solving multi-criterion problems of optimization [1, 2].

Our strategy for solving the problem under study is based on the simple fact that each parameter in $\mathbf{T_1, ..., T_n}$ vectors as related to the corresponding parameter in $\mathbf{T_0}$ can be, irrespective of the way of its definition, assessed in terms of only one linguistic variable of "close" type. In that event the problem of choosing a technology amounts to the problem of comparing vectors $\mathbf{B_i}$ (i=1..n) where each component $\mathbf{B_{ij}}$ (i=1..n, j=1..m) will equal the value of the linguistic variable of "close" type and will correspond to the measure of closeness of the value of $\mathbf{P_j}$ parameter of $\mathbf{T_i}$ vector to its value in T0 vector. It is clear that depending on the means of defining the parameter the measure of closeness can be either calculated or assessed by an expert.

Let us consider an example that illustrates one way of solving our problem.

Let us suppose that there are five parameters that describe technology $\mathbf{T_0}$

$$\mathbf{T_0 = T_0 \ (P_1, ..., P_5)}$$

and the expert is asked to assess each parameter by decimal fractions from 0 to 1. Notice that some assessments will be of subjective character while others may be measurable ones. In spite of that the assessments should be on the same scale.

Let us assume that as a result of the examination we have obtained vector $\mathbf{B_0}$ that forms a fuzzy set

$\mathbf{B_0}$ =

P_1	P_2	P_3	P_4	P_5
0.5	1	0.8	1	1

Let in the data base there is $\mathbf{T_i}$ technology, that in the same manner can be written as

$\mathbf{B_i}$ =

P_1	P_2	P_3	P_4	P_5
0.8	1	0	0.4	0.3

Let us construct $\mathbf{B_{0i}}$ vector using the following rule

If $\mu_{Bi}(P_j) >= \mu_{B0}(P_j)$ then $B_{ij} = 1$

and

If $\mu_{Bi}(P_j) >= \mu_{B0}(P_j)$ then $B_{ij} = 1 - \mu_{B0}(P_j) + \mu_{Bi}(P_j)$ (j-1..m)

As a result we'll obtain a vector

$$B_{0i} = (1, 1, 0.2, 0.4, 0.7)$$

Then the coefficient of adequacy (closeness) $\mathbf{K_{BiB0}}$ can be determined as follows

$$K_{BiB0} = \frac{1+1+0.2+0.4+0.7}{5} \approx 0.66$$

Obviously if we have technologies $\mathbf{T_1, ..., T_n}$ then in the same manner we can calculate coefficients of adequacy $\mathbf{K_{B1B0}, ..., K_{B5B0}}$ and as a solution we can choose the technology that has a higher coefficient of adequacy.

We have described one possible way to assess closeness of technologies, there exists other ones, see for example [3]. It is evident that such a problem can also be solved in terms of image recognition using the theory of fuzzy sets and other more "subtle" measures of closeness.

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