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The Model of Assessment of Strategic Resources of Industrial Enterprise on the Basis of Fuzzy Set Theory

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Abstract: The present article is dedicated to evaluation of continued possibilities of the Company for its effective activity in the long-run period conduction. The assignment of strategic potential of an enterprise allows the manager to come to a conclusion about the level of organization maturity as to the implementation of innovative projects, to identify the strong and weak features of the enterprise in terms of the process of implementation and management of innovations and to make the appropriate adjustments in tactics and strategy of enterprise development. However, the lack of consideration of uncertainty in the assessment model results in a significant error of appraisal value. Nowadays on the competitive market such an error is unacceptable. One of the key problems of definition of economic-mathematical model of strategic variants of enterprise development choosing is related to the uncertainty of environment and lack of complete and accurate information. On the basis of fuzzy-set theory the model of assessment of quality of strategic resources of an enterprise taking into account the uncertainty factor was suggested. The model has the variety of advantages in comparison with the method of expert and statistical estimations that allow us to minimize the error of the received assignments. The results of researches can be used as the means of extension of instrumental and mathematical tools of enterprise strategic objectives modeling in the process of management decisions taking.

Key words: Fuzzy-set theory · Industrial enterprise · Uncertainty factor

INTRODUCTION

Under conditions of market relations the provision of effective functioning and competitive positions of an industrial enterprise is possible only with the availability of an effective production control system of the enterprise. It should be noted that the process of production management as a complex system includes two key elements: strategic and operating management. These two elements are closely interrelated and interdependent. Thus, the operational and production activities of the enterprise are the basis of intermediate objectives of strategic management. In its turn the strategic management assigns the vector of realization of operative and production activities of the enterprise. It is evident that both the strategic and operative management are using one and the same resources. However, if during the operative and production management one can not always achieve the high level of quality of the applied resources due to the cyclical fluctuations of the indicator, then during the strategic management more stringent requirements to the quality characteristics of applied resources are imposed. That's why the assignment and the analysis of strategic resources of the enterprise are the most important element of the enterprise management performance. Thus, the object of the present article is to create an extremely accurate universal model of assessment of quality of strategic resources of the enterprise which permits the avoidance of uncertainty based on original statistical data.

MATERIALS AND METHODS

As a part of socio-economic system we can exhale the following subsystems (strategic resources): technical resources; technological resources; human resources; spatial resources; management system resources; informational resources; financial resources [1, p.38].

Figure1 shows the interrelation of strategic resources of the enterprise. On the picture the informational resources were not shown advisedly as a separate block, but they are reflected with the arrows directional tracking as to the key components of potential.

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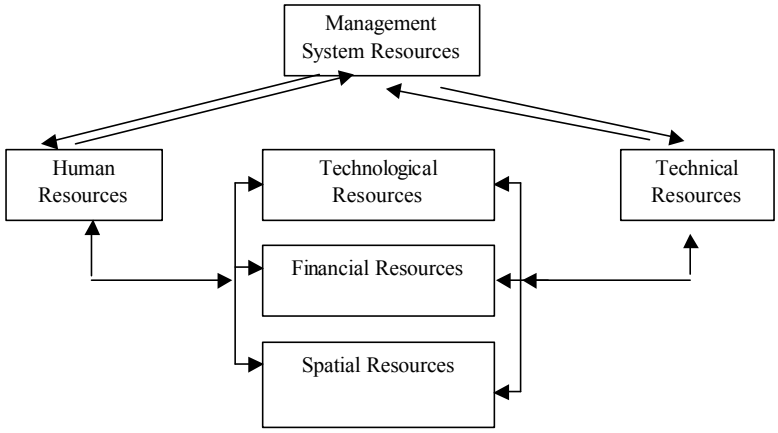

Fig. 1: The correlation of strategic resources of enterprise

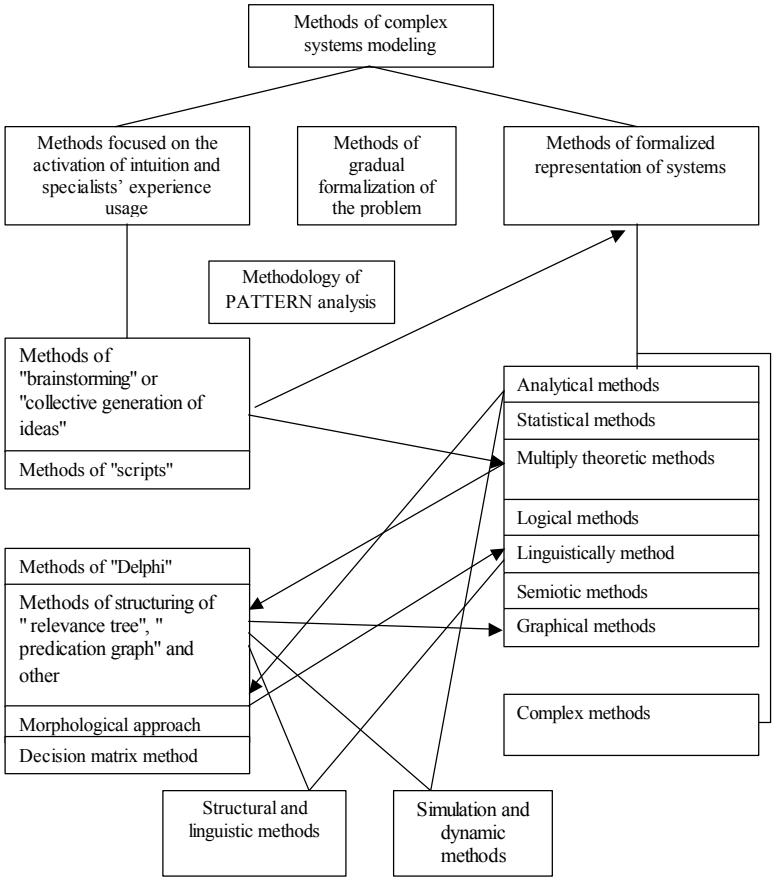

Fig. 2: The scheme of representation methods and analysis systems

There is a broad range of methods of performance and system's evaluation. In general, all the methods of assignment of the socio-economic indicators can be divided into three groups: methods based on expert assignment, methods based on formalization of socio-economic data and mixed methods which generalize the first two groups (Fig. 2).

On practice, the most spread methods of assignment of socio-economic indicators are the following two subgroups of methods: the method of expert assignment and statistic methods in their various displays. Such popularity of these methods is related to their simple and easy implementation and minimal amount of preparatory and auxiliary activities. However, for creation

Table 1: Main characteristics of method of expert estimates and statistical method

Method of evaluation performance	Positive characteristics	Negative characteristics
Method of expert estimates	the capability to estimate the quality indicators.	1) Subjectivity of expert estimates; 2) Is not always based on mathematical calculations; 3) Complexity (at "Delphi" method).
Statistical method	Is based on mathematical calculations and numerical data.	1) Inaccuracy due to lack of large continuous sampling of origin data; 2) Inability to assess the qualitatively expressed indicators.

of adequate and accurate model of assessment of strategic resources of enterprise these methods can not be used in their pure form due to the presence of a number of negative characteristics described in Table 1.

Usually the method of expert assignments and statistical method are both present in the analyses of economic indicators that have a discrete quantitative (numerical) representation. In this case the disadvantages of one method of analysis are eliminated by the advantages of another method. However, even such combined approach to assessment of economic indicators has some disadvantages as well. This is due to the fact that the accuracy of the estimation of probabilities of event implementation depends on various factors starting from the statistical information and finishing with the quality of expert assignments. In other words, there is some uncertainty in the assignment of one or another economic indicator. The absence of accounting of uncertainty in the estimation model leads to significant errors in assignment results. Under current conditions of competitive market such an error is unacceptable. That's why in recent years for assignment of phenomena with a high degree of uncertainty which also present in economy the rapidly developing branch of mathematics – the fuzzy set theory is used.

The fuzzy set theory describes the definitions and processes in which the parameters and objects have no clear scopes and borders. The basis of application of fuzzy set theory is in the method of expert assignments which sometimes can be built on the basis of probabilistic method.

However in such case the key disadvantages of the method of expert assignments and the probabilistic method can be eliminated through accounting in uncertainty model. The ordinary set is defined by its characteristic function which takes the value 1 if the given point belongs to the set and the value 0 if not. Nevertheless, there is another big category of concepts that can not be described in terms of classical set theory. The principal feature of these concepts is the existence of blurred scopes and borders between the different gradations of one or another quality. In real, the scopes and borders between these concepts have indistinct (fuzzy) character. For such concepts description the fuzzy sets, the characteristic functions of which can possess the values from the entire range of 0 to 1 (i.e. the point is characterized by a measure of its accessory to the set) are used. Such approach makes it much easier to implement the method of expert assessments than the traditional theory of probability. The model formulation in frames of indistinct (fuzzy) approach gives the opportunity to compare the models and to give an exact meaning to such definitions as "high", "low", "most preferred", "highly anticipated", "most likely", etc.

Here appears what is called in the science the "linguistic variable" with its value of array, while the connection of quantitative value of a factor with its quality linguistic description is given by the so-called membership functions of factor to the fuzzy set.

The integrated algorithm for assignment of economic indicator maintaining with the help of fuzzy set theory implementation is shown on Fig. 3. The essence of this algorithm lays in the sequential movement of researcher from the array of linguistic variable to the actual value of examined indicator which also achieves the linguistic meaning as a result of assignment making.

Main Part: The assignment of economic indicator with the help of fuzzy set theory implementation is conducted in two integrated steps. Let's describe each of these steps.

The *preparation step* is divided into several successive steps.

Step 1: Let's enter a set of separate indicators of $P = \{P_{ij}\}$ which foremost characterize the quality of strategic resources of the enterprise.

The methodological and practical issues of quantitative estimation of quality are the subject of qualimetry - the science of measurement and evaluation of the quality of various products of labor [2]. In qualimetry the quality is examined as hierarchical set of characteristics and properties which are represented by a tree of indicators. On Fig. 4 the indicator P_i that takes

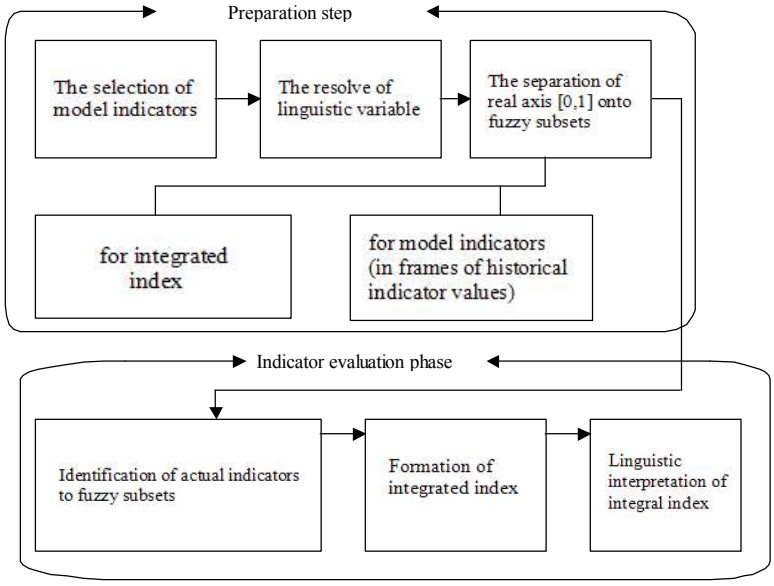

Fig. 3: Algorithm of economic indicator estimation on the basis on fuzzy set theory.

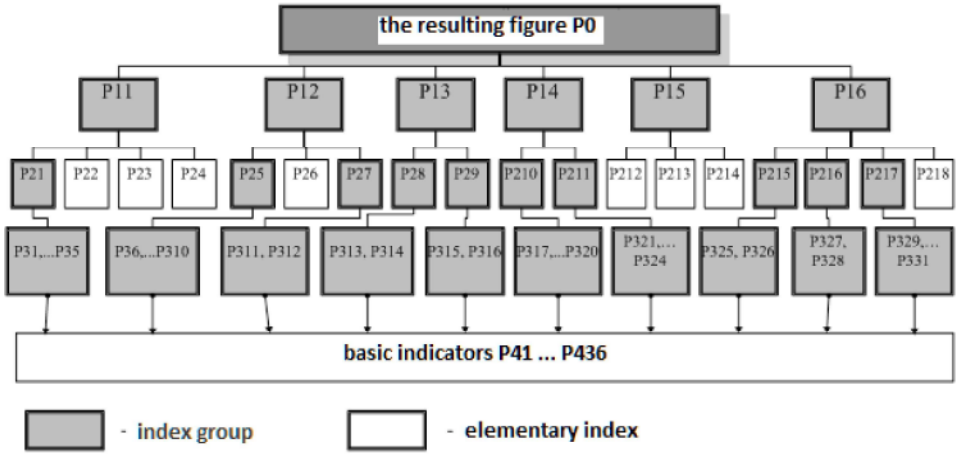

Fig. 4 The quality evaluation indicator tree of strategic resources of enterprise

account of complex characteristic of quality of the examined object is on the lowest, zero level, while the components of its characteristic - the quality of technical resources (P11), the quality of technological resources (P12), the quality of spatial resources (P13), the quality of management system resources (P14), the quality of information resources (P15) and the quality of human resources (P16) – are placed on the higher level in the hierarchy.

On the second level of examining each characteristic of the first level is decomposing into the less complicated characteristics and namely:

Indicator P_{11}: Onto indicator of production equipment capabilities P_{21}; the indicator of quality of the used raw materials and components (easy-to-sell goods, works, services) P_{22}; the indicator of rationality of raw materials and components P_{23} implementation; the indicator of modernization and reconstruction of equipment and their enforcement P_{24};

Indicator P_{12}: Onto indicator of technology possibilities in the process of ensuring of stability of quality of the products (works, services) P_{25}; the indicator of equipping with advanced technological resources P_{26}; the indicator of competitive ideas for technological resources development P_{27};

Indicator P_{13}: Onto indicator of compliance of production facilities and territories to strategic objectives of organizational system P_{28}; the indicator of connectivity P_{29};

Indicator P_{14}: On indicator of management state in external environment of organizational system P_{210}; the indicator management state in internal environment of organizational system P_{211};

Indicator P_{15}: On indicator of availability and sufficiency of database about the external environment P_{212}; the indicator of reliability, accuracy and actual continuity of information about the external environment P_{213}; the indicator of expandability and improvement of accuracy and actual continuity of information about the external environment P_{214};

Indicator P_{16}: On indicator of management personnel capacity P_{215}; the indicator of industrial personnel capacity P_{216}; the indicator of effectiveness and reliability of personnel work P_{217}; the indicator of personnel training and certification P_{218}.

On the third level of hierarchy each characteristic of the second level is decomposing into the more complicated characteristics and namely:

Indicator P_{21}: On indicator of operational status of technological equipment P_{31}; the indicator of operational status of equipment and tools P_{32}; the indicator of technical maintenance and repair P_{33}; the indicator of metrological provision P_{34}; the indicator of frequency of occupational injuries P_{35};

Indicator P_{22}, P_{23}, P_{24}: Are listed above;

Indicator P_{25}: On indicator of products (works, services) stability P_{36}; the indicator of state of construction and technological documentation P_{37}; the indicator of state of laboratories and testing facilities P_{38}; the indicator of state of technological processes control and management P_{39}; the indicator of state of control of quality, raw materials and products P_{310} ;

Indicator P_{26}: Are listed above;

Indicator P_{27}: On indicator of ability of competitive ideas putting forward P_{311}; the indicator of ability of competitive ideas implementation P_{312};

Indicator P_{28}: On indicator of suitability of system organization to planning and nature-oriented regulations P_{313}; the indicator of management solutions in the field of architectural and planning activities P_{314};

Indicator P_{29}: on indicator of level of automatization and connection P_{315}; the indicator of level of information support P_{316};

Indicator P_{210}: On indicator of commercial range of goods management P_{317}; the indicator of transaction expenses management P_{318}; the indicator of price formation management P_{319}; the indicator of foreign economic policy management P_{320};

Indicator P_{211}: On indicator of quality management P_{321}; the indicator of personnel management P_{322}; the indicator of investment activity management P_{323}; the indicator of operating expenses management P_{324};

Indicator P_{215}: On indicator of managerial personnel capacity P_{325}; the indicator of specialists capacities P_{326};

Indicator P_{216}: On indicator of key industrial personnel capacity P_{327}; the indicator of supporting personnel capacities P_{328};

Indicator P_{217}: On indicator of level of labor discipline P_{329}; the indicator of reliability of work of personnel P_{330}; the indicator of equability of man-loading P_{331}.

On the forth level of hierarchy of quality of strategic resources of the enterprise each characteristic of the third level is decomposing into the following characteristics:

Indicator P_{311}: On indicator of capabilities to put forward the competitive ideas in the sphere of goods manufacturing P_{41}; the indicator of capabilities to put forward the competitive ideas in the sphere of technologies P_{42}; the indicator of capabilities to put forward the competitive ideas in the sphere of production enterprises P_{43};

Indicator P_{312}: On indicator of capability to implement the competitive ideas in the sphere of goods manufacturing P_{44}; the indicator of capabilities to implement the competitive ideas in the sphere of technologies P_{45}; the indicator of capabilities to implement the competitive ideas in the sphere of production enterprises P_{46};

Indicator P_{313}, P_{314}, P_{315}, P_{316}: Are listed above;

Indicator P_{317}: On indicator of the level of consumer's satisfaction P_{47}; the indicator of duration of mastering and introduction of products to the market P_{48}; the indicator of marketing state P_{49};

Indicator P_{318}: On indicator of legal footwork of transaction P_{410}; the indicator of selected standing orders of market relations regulation P_{411}; the indicator of commitment of potential partners for cooperation P_{412};

Indicator P_{319}: On indicator of correspondence of price policy to the market type P_{413}; the indicator of correspondence of price policy to the Product lifecycle P_{414}; the indicator of correspondence of price policy to the general objects of organizational system P_{415}; the indicator of acceptability of price policy for the consumer P_{416};

Indicator P_{320}: On indicator of monitoring of national economy P_{417}; the indicator of enterprise of international marketing system P_{418}; the indicator of capabilities for foreign economic policy volume increasing P_{419};

Indicator P_{321}: On indicator of state of quality control system P_{420}; the indicator of capabilities for quality system development P_{421};

Indicator P_{322}: On indicator of ensuring of compliance of personnel structure to the requirements of organizational system P_{422}; the indictor of formation of stable interest of the personnel in the results of organizational system functioning P_{423};

Indicator P_{323}: On indicators of private business activity investing P_{424}; the indicator of outward investments of organizational system P_{425};

Indicator P_{324}: On indicator of commitment of organizational system to specified allowances P_{426}; the indicator of strategic cost-benefit analysis P_{427};

Indicator P_{325}: On indicator of competence of managing personnel P_{428}; the indicator of correlation of number of managing and industrial personnel P_{429}; the indicator of capacity of managing personnel to adapt to changes of organizational system objects P_{430};

Indicator P_{326}: On indicators of level of qualification and competence of specialists P_{431}; the indicator of capacity of specialists to adapt to changes of organizational system objects P_{432};

Indicator P_{327}: On indicator of qualification of the key industrial personnel P_{433}; the indicator of availability of the key industrial personnel P_{434};

Indicator P_{328}: On indicator of qualification of supporting industrial personnel P_{435}; the indicator of availability of supporting industrial personnel P_{436} [1, p.56].

The model excludes the breakage in numerical values of the indicators mentioned above as for assignment of strategic resources we use not an absolute indicator values but their fractions from the actual maximum value for the period. For assignment the integral value of groups of indicators of the first level received through summing up of the weighted indicators in the group are used.

Step 2: Let's set the linguistic variables and fuzzy subsets we need for the assessment making. Due to the fact that the assignment of integral indicator is made with the great number of indicators usage, it is very difficult to make the assignment of each indicator of the model on the basis of the fuzzy-set approach. That's why first of all we will calculate the value of groups of indicators of the first level (P_{1j}), after which we will make the assignment of them through the fuzzy set theory implementation with the following convolution into the integral indicator. That's why let's enter the two linguistic variables with the corresponding arrays (Table 2).

Step 3: Let's form the classifier of the current value of quality of strategic resources of the enterprise *qsr* as a criterion for partitioning of the given sets on fuzzy subsets. This classifier is a standard five-level classifier on the 01-carrier presented by Nedosekin A.O in his works [3, 4]. Let's briefly describe this classifier. In such classifier segment of the real axis [0, 1] (01-carrier) occurs as a carrier of linguistic variable. Such segment is universal as any segment of the real axis can be reduced to the interval [0, 1]. To describe the type of subsets of arrays we will enter a system that consists of five membership functions which characterize the degree of membership of segments values of 01-carrier in the given subset (Table 3).

Table 2: Arrays of linguistic variables

The linguistic variable QSR_i- the quality level of strategic resources	Array
QSR-1	Fuzzy subset "modest level or total absence of quality of resources"
QSR-2	Fuzzy subset "modest level of quality of resources"
QSR-3	Fuzzy subset "average level of quality of resources"
QSR -4	Fuzzy subset "high level of quality of resources"
QSR -5	Fuzzy subset "level limit of quality of resources"
Linguistic variable L_i- the significance level of group of indicators P_{1j}	Array
L-1	Fuzzy subset "the lowest level of group of indicators P_{1j}"
L-2	Fuzzy subset "modest level of group of indicators P_{1j}"
L-3	Fuzzy subset "average level of group of indicators P_{1j}"
L-4	Fuzzy subset "high level of group of indicators P_{1j}"
L-5	Fuzzy subset "the very high level of group of indicators P_{1j}"

Resource: authors

Table 3: Classification of innovation potential degree

qsr limits	Classification of parameter level	Membership function
$0 \le qsr \le 0,15$	QSR -1	1
$0,15 < qsr < 0,25$	QSR -1	$\mu_1 = 10*(0,25 - ip)$
	QSR -2	$\mu_2 = 1 - \mu_1$
$0,25 \le qsr \le 0,35$	QSR -2	1
$0,35 < qsr < 0,45$	QSR -2	$\mu_2 = 10*(0,45 - ip)$
	QSR -3	$\mu_2 = 1 - \mu_2$
$0,45 \le qsr \le 0,55$	QSR -3	1
$0,55 < qsr < 0,65$	QSR -3	$\mu_3 = 10*(0,65 - ip)$
	QSR -4	$\mu_3 = 1 - \mu_3$
$0,65 \le qsr \le 0,75$	QSR -4	1
$0,75 < qsr < 0,85$	QSR -4	$\mu_4 = 10*(0,85 - ip)$
	QSR -5	$\mu_4 = 1 - \mu_4$
$0,85 \le qsr \le 1$	QSR -5	1

Resource [5,6]

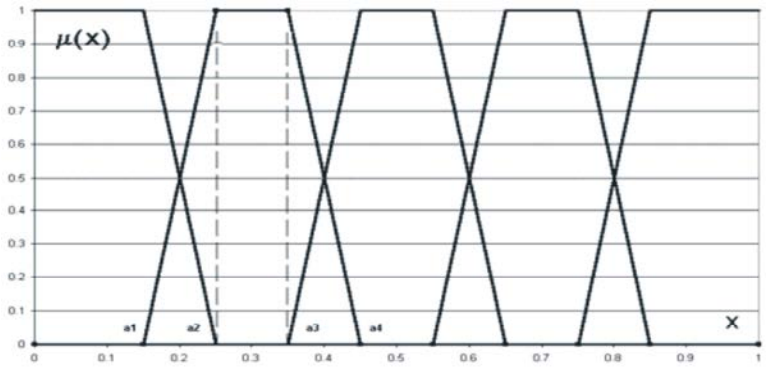

Fig. 5: Trapezoidal membership functions $\mu(x)$

Graphically, the set of membership functions of the term will appear as shown in Fig. 5. The graph shows trapezoidal membership functions, where the axis of ordinates shows the values of the membership functions (0 to 1) and the axis of abscissas shows the terms [3, p.112]. At that, the upper base of trapezoid corresponds to the absolute confidence of the expert in the correctness of his classification and the lower base characterizes the confidence in the fact that no other values of the range (0; 1) do not fall in the selected fuzzy subset. Side faces of trapezoids reflect fluctuation of judgment of the expert (the group of experts) on the membership of a particular line segment on 01-carrier to a particular term. Creating a system of fuzzy subsets involves the introduction of a set of double points which are the abscissas of the middles of the upper trapezoids of the classifier. In this case, we have five double points: {0,1; 0,3; 0,5; 0,7; 0,9}.

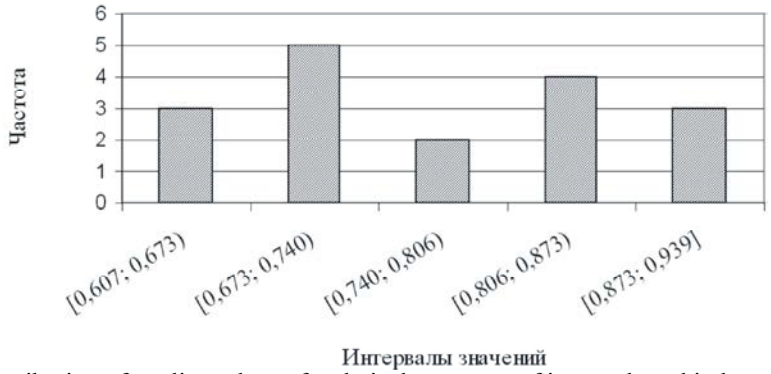

Fig. 6: Frequency of distribution of quality values of technical resources of iron and steel industry enterprise

Step 4: Let's create a system of classifiers of group of P_{1j} indicators as a criterion of partitioning of the full set of their values to fuzzy subsets of L kind. As the values of group of P_{1j} indictors are unique to each enterprise, the fuzzy subsets of their values do not necessarily have to be equal among them and symmetrical. To build the classifiers of group of P_{1j} indicators, it is necessary to investigate their frequency distribution in the actual ranges of their appearance. Fig. 6 shows the frequency distributions of the quality of technical resources of one of the leading enterprises of ferrous metallurgy. Indicator of the study period is from 2007 to 2011 inclusive.

Creating a classifier begins with determining the values of the indicator that can be called "average." It is obvious the range of indicator values, the frequency of falling into which is highest, contains the average value of the indicator. Also, it is necessary to take into account the fact that the average value of the indicator is close to the median of the distribution. So, that value of the indicator will be average which is to the maximum extent close to both the range with the highest frequency and the median of the distribution of indicator values.

In our case, the distribution of group of indicator values of a technical resource is not homogeneous, as there is a polarization of frequencies between minimum and maximum values. Therefore, the average value of the indicator contains the median range which is equidistant to the ranges of values with the highest distribution frequencies. Further, based on the distribution frequencies of the indicator located to the right and to the left of the range containing the median segment, interval values of the indicator for the remaining term are defined by experts. It should be noted that since the highest distribution frequencies of the values studied group of indicators are observed in the second and fourth ranges, arrays "average of indicator" [10, p.5-7] will have the biggest line segments of uncertainty of all selected sets. The resulting classification for each indicator and subset of arrays are described by four T-numbers:

$$(a_1,a_2,a_3,a_4) \quad (1)$$

where a_1, a_4 is the abscisse of the lower base of trapezoidal membership function; and a_2, a_3 is the abscisse of the upper base of trapezoidal membership function.

The classification of instantaneous values of indicators of quality of technical resources is given below in Table 4.

After preparatory actions follows the stage of assignment of economic indicator. This stage consists of four steps.

Step 1: Let's calculate the levels of groups of indicators P_{1j} of exact enterprise.

Step 2: Let's find out the indicator values of quality of strategic resources of the enterprise in accordance with λ_{ij} criteria which characterizes the level of membership of particular indicator value of arrays to the fuzzy subsets.

Table 4: T-integer for wear coefficient value of basic means of iron and steel industry enterprise

Value of linguistic variable L_i				
«very low»	«low»	«average»	«high»	«very high»
(-8; -8; 0,635; 0,660)	(0,635; 0,660; 0,696; 0,740)	(0,696; 0,740; 0,806; 0,850)	(0,806; 0,850; 0,885; 0,925)	(0,885; 0,925; +8; +8)

Resource: authors

The essence of λ_{ij} criteria for the build-up model of assignment leis in fact that it brings the values of the studied indicators to the comparable form correlating them with the particular values of 01-carrier. The values of λ_{ij} criteria lay in the open interval [0; 1]. The λ_{ij} criteria can be calculated as follows:

$$\lambda_{ij} = 1 - \frac{X_{ij} - a_3^*}{a_4^* - a_3^*} \quad (2)$$

where $a_3^*, ?_4^*$ is a T-number of the 1st subset of arrays which the studied indicator belongs to.

Step 3: Let's built the integral indicator of assignment of quality of strategic resources of the enterprise (qsr) through convolution of results of assignment of indicators of quality of different types of strategic resources:

$$\text{qsr} = \sum_{k=1}^{5} qsr_k * \lambda_{ij} \quad (3)$$

where qsr_k are double points of 01-carrier.

Step 4: On the basis of numeral value of integral indicator let's make its linguistic interpretation with determination of the level of membership of indicator value to exact therm. In this case the order of work will be the same as describe in step 2 of the current stage of the model. First we will find the subset (subsets) of 01-carrier which includes the calculation of integral indicator value. Then as the result of calculation of λ_{ij} criteria for the integral indicator we will get the linguistic interpretation of the current value of quality of strategic resources of the enterprise and the index of confidence of the expert in the similar interpretation of indicator which expressed as the λ_{ij} index. The interpretation of integral value of quality of strategic resources is more suitable to make with the help of Table 3 usage.

CONCLUSION

By this means, as the results of the study we have got the built-up universal model of assignment of the quality of any component of strategic resources of the enterprise. A distinctive feature of the fuzzy-set approach used in the model is the possibility of excluding of ambiguity and uncertainty of the measured indicators that arisen as a result of subjective judgments of experts and their influence onto the original data of indirect external factors. As a result of such advantage the accuracy of assignments and the quality of the taken strategic decisions are significantly increasing. In addition to this, the developed model has a high degree of flexibility which allows to make the assignment of any socio-economic process described by any specific indicators.

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