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ABSTRACT

of the dissertation for the degree of Doctor of Science

DEVELOPING SCIENTIFIC-METHODOLOGICAL BASIS FOR INTELLECTUAL MANAGEMENT OF HUMAN RESOURCES IN TERMS OF INFORMATION SOCIETY

Specialty: 3338.01 - "System analysis, control and information processing"

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GENERAL CHARACTERISTICS OF THE STUDY

The relevance of the study. Comprehensive development of information and communication technologies has led to complex changes in all spheres of human activity, making the formation of information society a reality. Adaptation of the public administration to the development of the information society is accompanied by the establishment of national e-government infrastructures, including human resources management (HRM) infrastructure, which emphasizes the principles of transparency, mobility and interactivity and serves to the welfare and prosperity of population. Establishment of the electronic infrastructure of HRM, defined by the formation, use and development of human resources, management of supply and demand for human resources, analysis and forecasting of demographic situation, integration of socially disadvantaged groups into the workforce, comprises the development of scientifically grounded approaches to problem solving and decision making with use of innovative technologies.

Industry 4.0, which supports the application of innovation in all areas and is characterized by Artificial Intelligence, Big Data, Internet of Things, etc., changes the structure of occupations, calls for new skills and habits, adaptation of knowledge and skills to the needs of a dynamically changing environment, and requires the formation of human resources that meet the requirements of an innovative economy. Taking into account the changes in the attitudes towards human resources, and their transformation into an important and key factor in the innovative economy, and stating from the realities of information society, it is relevant to explore the scientific-theoretical problems of HRM and to develop its scientific and methodological basis.

At present, the concept of human development, formulated by the thesis that “People are the real wealth of a nation. The basic objective of development is to create an enabling environment for people to enjoy long, healthy and creative lives”[1], has shaped a new world trend in the development of HRM theory and practice. It has shifted it from the paradigm of HR management to multi-level HRM system. In this regard, the human resources of the country are distinguished at the micro level - organization (enterprise, firm), meso level - certain segment of the economy (region, sector) and macro level - country: in the organization, HRM represents the attitude of human resources as the key resource of the organization; in certain sectors of the economy, HRM is characterized by the management of supply and demand for human resources in this segment; at the national level, human resources are the main indicator of the economic development of each state, representing the intellectual potential, knowledge and skills of the population[2].

The main objects of HRM system, which is formed at the management levels, include a human and his/her competencies, the personal and behavioral qualities, motivation values, intellectual and qualifying potentials determined by his/her knowledge, skills and professional capacity. The goal of HRM, which has become a specific type of management activity, is to make scientifically-grounded decisions referring to the socially oriented innovative approach that prioritizes an individual and all the values that he/she possesses to achieve the goals set out depending on a specific issue.

The population, labor resources of a country, and the personnel of industries, mixed or government entities, etc. are the research objects of HRM decision support issues for the hierarchical levels of management and characterized by a large number of indicators, due to which the multi-factorial and multi-criterial nature of HRM issues and the uncertainty of these factors are ensured. On the other hand, HRM is influenced by economic and social processes. These processes include the development of advanced technologies, the recognition of education and knowledge as a valuable asset of any society, the impact

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[1] UNDP Human Devolopment Report, 1990. (p.9)

[2] Управление человеческими ресурсами: учебник для бакалавров / под ред. И. А. Максимцева, Н. А. Горелова, 2-е изд., перераб. и доп., М.:Издательство Юрайт, 2014, 526 с. (p.23)

of demographic processes on the formation of human resources, and so on. These determine the variability and dynamic nature of the research object, its characteristics, the prerequisites for HRM decision-making, and the use of expert knowledge in the decision-making process. The modeling of relevant uncertainties, the formation of expert knowledge, the generation, selection and support of management decisions require the development of acceptable models, methods, algorithms and tools for decision-making processes referring to fuzzy mathematical apparatus.

The goal of the dissertation is to develop the models, methods and tools for the intellectual decision support in the HRM infrastructure of e-government.

To achieve this goal, the following **research issues** are set:

- to analyze the scientific and theoretical aspects of HRM in the context of the information society and to identify the issues of decision support for the management of hierarchical human resources across the country;
- to determine the role of demographic indicators in decision support that forms the human resources and socio-economic policies of the state, to analyze them and to develop the models and methods for their forecast;
- to model the decision support on poverty reduction in the country and the formation of promising employment policies, and to develop solution methods and algorithms;
- to model the HRM issues that require an intellectual support at micro level, i.e. in the organization, to develop decision-making methods and algorithms;
- to develop the primary information processing methods for intellectual HRM decision support.
- to analyze the situation related to the formation, use and development of human resources at meso level, i.e., in the medical field, and to develop the methods and algorithms for HRM decision support.

The research methods are based on fuzzy set theory, decision theory, fuzzy time sequences, multi-criterial selection and ranking methods, analytical hierarchy process (AHP), situational analysis, fuzzy pattern recognition techniques.

Basic provisions set for defense:

- scientific and theoretical aspects of HRM in the information society, and HRM decision support issues at various levels of management are identified;
- the model, method and system for demographic indicators forecasting are developed to support decisions at the macro level that shape the human resources and socio-economic policies of the state;
- the model, methods and algorithms for decision support on poverty reduction and the formation of a promising employment policy in the country are proposed;
- comprehensive assessment model of HRM issues, multi-criteria decision methods, algorithms and tools, which require intellectual support at micro level, i.e., in the organization, are developed;
- initial information processing methods for intellectual HRM decision support are proposed;
- the situation related to the formation, use and development of human resources at meso level, i.e., in the medical field, is analyzed, and decision methods and algorithms for multi-scenario solutions to balance the supply and demand for medical professionals are developed.

The scientific novelty of the dissertation is determined by the following **results**:

- HRM decision support issues on the hierarchical levels of governance in the information society are identified and the need to use the fuzzy mathematical apparatus for their modeling are justified;
- at macro level - a method of forecasting demographic indicators and the intellectual demographic forecasting system (IDFS) based on fuzzy time sequence model are developed;
- at macro level - a hierarchical structure of the labor market (LM) is proposed based on a comprehensive approach to the

impact factors, as well as the methodology for its prognosis and planning based on multi-scenario approach and AHP, and the efficiency assessment method are developed;

- at macro level - a method for assessing family income is developed to identify low-income families in the poverty reduction system;
- at micro level - a comprehensive assessment model for HRM issues in the organization, and relevant solution algorithms and HRM decision support system based on additive and multiplicative aggregation are developed;
- at micro level - a mathematical representation of the multi-criteria optimization problem for HRM decision support in the organization is given, a TOPSIS (*Technigue for Order Preference by Similarity to Ideal Solition)* modification and IAM-based solution method are developed, and a recruitment decision support methodology is proposed and implemented on phases;
- at micro level – the methods for selecting and evaluating employees in virtual organizations (VOs) are proposed;
- at meso level - scenarios are developed for balancing the supply and demand for medical professionals taking into account the variability, the appropriate decision methods based on fuzzy pattern recognition, and the methodology for solving employment issues are developed and implemented on phases.

Theoretical significance of the research is determined by the development of scientific and methodological bases to support decisions on hierarchical levels of human resources referring to fuzzy models and methods. The proposed models, methods and algorithms, along with their application, necessitate their development and modification, and the mathematical basis for decision-making is developed to address poorly structured and formulated issues. Methodological bases of intellectual HRM decision support are designated by:

- the development of the method and relevant tools for forecasting demographic indicators of population at macro level, the methodology for LM forecasting and planning, income assessment of low-income families to support decisions on human resources and socio-economic and employment policy of the state;

- the development of decision methods and multi-criteria optimization methods based on additive and multiplicative aggregation for the solution of HRM issues that require intellectual support at micro level, i.e., in the organization, and the creation of appropriate tools;
- the development of multi-scenario decision methods and algorithms to balance supply and demand at meso level, i.e., in the medical segment.

Practical significance of study. The results obtained in the dissertation work focus on the application methods of intellectual support systems of HRM decisions. The proposed methods and algorithms are brought to the appropriate computations and to the synthesis procedures' level of intellectual support systems for HRM decisions realized on a personal computer basis, and to the development and implementation of tools and applied software packages for human resources management on hierarchical levels across the country.

Realization and application of results. The main results are achieved from the implementation of the research work on the "Theoretical and technical problems of information technology" within the framework of the fundamental research of the Azerbaijan National Academy of Sciences. The main scientific and theoretical results are recognized by the Presidium of ANAS and the Department of Physical and Mathematical and Technical Sciences and are included in the annual reports for the years 2004, 2009, 2010, 2011, 2015, 2017, 2018 and 2019.

Approbation of research: The main scientific-theoretical and practical results of the research are reported and discussed at the following conferences:

International conference Soft computing Technologies in economics ICSCTE–2007, Bakı, 19–21noyabr 2007; The Third

International Conference on “Problems of Cybernetics and Informatics”, September 6–8, 2010, Baku; V International Conference Application of Information and communication technologies, October 12–14, 2011, Baku; IV International Conference on “Problems of Cybernetics and Informatics”, September 12–14, 2012, Baku; Искусственный интеллект. Интеллектуальные системы - Международная научно-техническая конференция ИИ-2013, 23–27 сентября 2013 года, Донецк, пос. Кацивели; 9th IEEE International Conference on Application of Information and communication technologies, AICT2015, Rostov-on-Don, 14–16 October, 2015; 2nd International Conference on Information Science and Control Engineering (ICISCE 2015), 24–26 April 2015, Shanghai, China; “Elektron tibbin multidissiplinar problemləri” I respublika elmi-praktiki konfransı, Bakı, 24 may 2016; 3rd International Conference on Advanced Technology & Sciences (ICAT16), Konya, Sep. 01–03, 2016; The 6th International Conference on Control and Opimization with Industrial Applications (COIA-2018), Baku, 11-13 July, 2018; “Azərbaycanda sosial müdafiə sisteminin inkişafi: dünən, bu gün və sabah” mövzusunda beynəlxalq elmi-praktik konfransı, Bakı, 26 dekabr 2018.

Scientific publications: On the results of the dissertation, 38 scientific papers: 23 articles, including 14 articles published in foreign prestigious journals in accordance with the requirements of the HAC, 12 proceedings, 2 book and 1 express information were published.

Structure and scope of the work: The dissertation consists of 404 pages including the introduction, 5 chapters, conclusion and a list of 321 references, 50 figures and 96 tables.

BRIEF DESCRIPTION

Introduction justifies the relevance of the dissertation theme, identifies the goals and problems of the research, presents the main scientific innovations, theoretical and practical significance of the work and provides information on the application and approbation of the proposed models and methods.

Chapter 1 analyzes the scientific-theoretical aspects of HRM, its essence, key concepts, development stages and models. In accordance with the principles of “human resources”, "economic human", "creative human", "multi-level management", the objectives and problems of HRM system are analyzed, and the modern approaches that constitutes the basis for HRM concept and the formation phases of the principles and methods are explained. It is noted that, in accordance with the modern approach that studies the HRM in a multi-level system, that is macro-, meso- and micro-levels, the human resource is a multi-planned concept defined by the development level, demographic situations, economic situation, employment, and so on for the development of society. According to this approach, the purpose of the HRM system is designated by the comprehensive study of the human resources, which are the main productive forces of society and the comprehension of the regularities of their reproduction at various stages of life in the interaction with the socio-economic and human resource policies of the state.

In accordance with the development stages of HRM concept, the HRM models are analyzed, and the functions of the subsystems of HRM system, namely the subsystems of formation, use, development and organization of human resources, are examined based on the multilevel model.

This chapter analyzes the human resource development indicators as a key strategic factor of the state, i.e., human development index, birth expectancy index, education index, national income index, living index, intellectual ratio, and so on, and the relevant issues to be solved (which requires the formation of research issues in the dissertation) are identified, and the situation on these indicators in Azerbaijan is interpreted in detail [16].

The last section of this chapter analyzes the issues of HRM decision support on the levels of hierarchical governance in HRM infrastructure of e-government, and identifies the research issues of the dissertation. It is argued that demographic changes should be taken into account at macro level, i.e. in all areas of the economic and social life of the state, in domestic and foreign policy. The importance of developing the alternative approaches with the application of the fuzzy models and methods in the monitoring and projection of demographic indicators of human resources is highlighted. The research in this area is stated to be consistent with the tasks set out in the State Program on Population and Demographic Development in the Republic of Azerbaijan (2014-2025).

It highlights the importance of forecasting and planning of LM to support appropriate decisions and measures to combat poverty and to provide employment, and emphasizes the significance of assessing the family income to define different strata of population, particularly low-income families and socially vulnerable groups to reduce the poverty and improve the quality of life. These studies are stated to be consistent with the objectives set out in the development concept of “Azerbaijan 2020: Looking into the Future” and recently adopted state programs for the development of human resources and the creation of an effective social protection system and employment in the country.

The development of mechanisms for the management of demand and supply of medical personnel based on intellectual technologies is considered to be a research matter, taking into account the analysis of the formation, use and development of human resources at meso-level, i.e. in the medical segment, the monitoring of supply and demand for medical personnel and the importance of assessing the demand for human resources.

This chapter highlights that, at the micro-level, the goal of HRM system, which is designed to provide the organization with staff, their efficient use, and professional and social development, is to achieve the global objectives of the organization while ensuring the objectivity and transparency of the decisions made. Numerous software products currently available at the intersection of HRM issues and information technology allow for the staff registry and support the salary calculations, recruitment, planning, training, evaluation, placement, motivation and so on. One of the major obstacles to the development of these systems is to ensure the confidentiality and security of employees' personal data. Thus, each organization that has access to all its employees' data must ensure the confidentiality and security of this information, regardless of the carrier in which this information is stored [21]. The personnel information in these systems is insufficient for optimal management decisions, thus, the hidden facts related to the professional activity of the staff, the dynamics of competence indicators, personal life, physical status, personal aspirations, etc. cannot be represented here. Given these aspects within the organization, the HRM decisions require referring to expert knowledge.

The object of this research includes the human resources at various stages of management, i.e. the population, labor resources of the country, personnel of industries, mixed or state enterprises, etc. All of them act as the carriers of numerous indicators, defining the multi-criterial and multi-factorial nature of HRM decisions and requiring to refer to expert knowledge and to form a decision-making in a fuzzy environment.

Taking into account all kinds of uncertainties, modeling of uncertainty in decision-making makes it necessary to refer to fuzzy mathematical apparatus[3] and requires the development of acceptable models, methods and tools for decision-making in HRM. This section analyzes the current situation, models, methods and tools for HRM decision support, and emphasizes the importance of considering the specifics of the certain issue in their development and the details of the environment in which they are formed.

[3] Zadeh L.A. Fuzzy Sets // Information and control, 1965, vol.8, no.3, pp.338–351.

Chapter 2 focuses on the analysis, modeling and development of appropriate solution methods for decision-making issues at macro level - that shape the human resources and socio-economic policies, demographic policies, employment and poverty reduction policies of the state. It is shown that the analysis of demographic processes and forecasting of population development is important in shaping and implementing effective social and economic policies of the country, ensuring sustainable development. Moreover, demographic analysis allows predicting HRM issues at macro-level and making relevant decisions [34]. However, the population with a large dynamic system functions under uncertainty, and being affected by the socio-demographic factors and due to the rapid demographic changes, the identification of prospective population changes is implemented in the fuzzy environment. Therefore, the technique for solving the prospective population changes within the fuzzy time series is proposed [1, 7].

Fuzzy time series. Assume that $U = \{u_1, u_2, ..., u_n\}$ – is a universal time set. The fuzzy set A of the universal set U is defined as follows[4]:

$$A = \{(\mu_A(u_1)/u_1), (\mu_A(u_2)/u_2), \dots ,(\mu_A(u_n)/u_n)\} \text{ or}$$

$$A = \{(\mu_A(u_i)/u_i)\},\ i = \overline{1, n},\ u_i \in U,\ \mu_A(u_i) \in [0,1].$$

where $\mu_A(u_i)$ is a membership function; $\mu_A(u_i): U \Rightarrow [0,1]$ is a degree of belonging of u_i to the set A; "/" is a division sign.

Let us assume that *Y(t) (t=...., 0, 1, 2...)*,which is a subset of set *R* of real numbers, is simultaneously a universal set on which a fuzzy set $\mu_i(t)$, *(t=1, 2, ...)* is defined, that is to say, the membership function is time-dependent. Let's define a set *F(t)* arranged out of $\{\mu_i(t), t=1,2,...\}$. More precisely, *F(t)* is a set of fuzzy sets *F(t)={μi(t), t=1, 2,...}*. Then *F(t)* is a fuzzy time series defined on a universal set *Y(t) (t=1, 2, 3....)*. It is evident, if *F(t)* is accepted as a linguistic variable, the fuzzy sets {*μi(t), t=1, 2,...}*. Out of which it is arranged that *F(t)* will assume the possible corresponding values of F(t). Besides, evidently, *F(t)* is time-dependent, which means, the function

[4] Song Q., Chissom B.S. Forecasting enrollments with fuzzy time series –part II // Fuzzy Sets and Systems, 1994, vol.62, pp.1–8.

F(t) will assume different values at different time moments.

Problem statement. The problem is described as follows: for a given time interval, data pertaining to the total population in Azerbaijan or to be clearer, the dynamics and respective variation of total population are available. The point is to find the anticipated total population based on the variations of the previous years.

Problem solution. In accordance with the description of the problem, the following forecasting methodology is proposed:

1. Finding appropriate variations of population dynamics in the country for a certain period.
2. Definition of the universal set U containing an interval between the least and greatest variations in total population.
3. Division of the universal set U into equal length intervals containing variation values corresponding to different population growth rates and the arithmetic mean of each interval to be found.
4. The qualitative description of variation values of total population as a linguistic variable, that's to say, determining the respective values of linguistic variable or the set of fuzzy sets F(t).
5. Fuzzification of the input data or the conversion of numerical values into fuzzy values, by the following formula.

$$\varphi_{A_j}(u_j) = \frac{1}{1+[C \cdot (U - u^j_{or.})]^2}$$

where U – variations; $u^j_{or.}$ is the middle point of the corresponding interval; C is a constant (in our case C=0.0001). C is chosen in such a way that it ensures the conversion of definite quantitative values into fuzzy values or their belonging to the interval [0, 1]:

$$A_j=(\varphi_{A_j}(u_j)/u_j \;\; u_j \in U, \;\; (\varphi_{A_j}(u_j) \in [0,1] \;\; .$$

This operation enables to reflect the corresponding numerical/qualitative values of qualitative representations of population growth rates in the value of membership function.

Figure 1 shows the uninterrupted membership functions of the fuzzy sets A_i, which describe the value of the linguistic variable "Variation of population number" for the period 1980–2001.

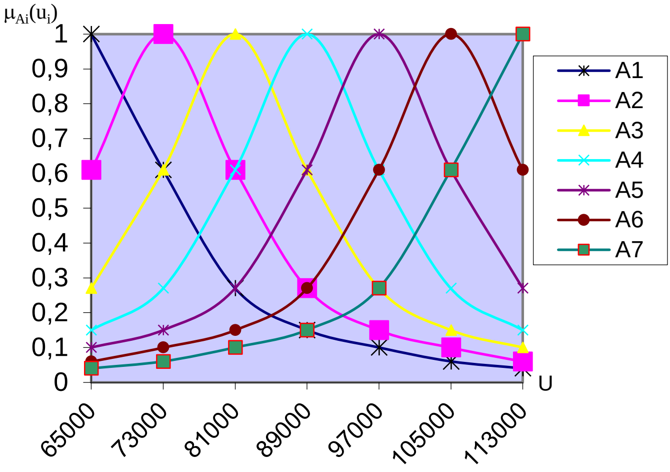


Figure 1. Graphic description of fuzzy sets of linguistic variable < Variation of population number> for the period 1980–2001

6. Selection of parameter w>1, corresponding to the time period prior to the concerned year. If $w = m$, the number of the population for years t-1, t-2, ..., t-m, t- $(m + 1)$ preceding the year t must be known in order to predict the population growth for year t.

7. Calculation of fuzzy relationships matrix $R(t)$ and forecasting of population growth in the next year. According to the method, the relationship matrix $R(t)$ is calculated at the next step:

$$R(t)[i,j]= O^w(t)\,[i,j] \cap K(t)\,[j],$$

or

$$R(t)=O^W(t) \otimes K(t) = \begin{vmatrix} R_{11} & R_{12} & \dots & R_{1j} \\ R_{21} & R_{22} & \dots & R_{2j} \\ \dots & \dots & \dots & \dots \\ R_{i1} & R_{i2} & \dots & R_{ij} \end{vmatrix}$$

Here:

- $O^W(t)$ is an operation matrix with dimension ixj for year t, i- number of lines and corresponds to the sequence of years t-2, t-

$3, ..., t\text{-}w$, j - number of columns and corresponds to the number of variation intervals.

- K (t) is a criteria matrix with dimension $1xj$ and a line matrix corresponding to the fuzzy variation of the number of population for year t-1
- $\otimes$ is an operation min ($\cap$).

Later the forecasted value $F(t)$ is defined for the year t as a fuzzy set as follows:

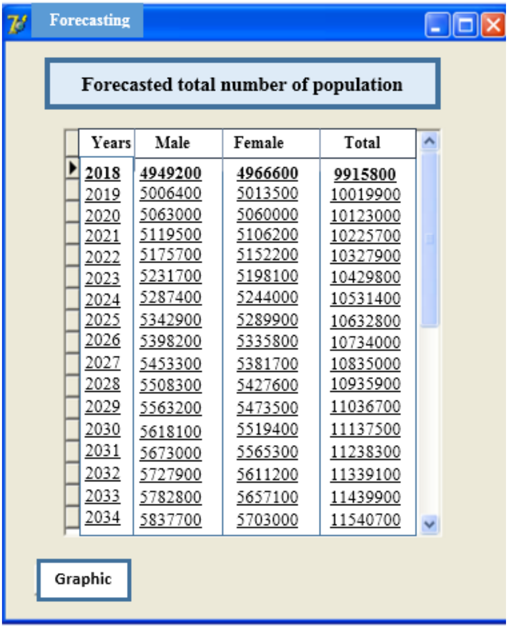
$F(t)=[Max(R_{11},R_{21},\ldots,R_{i1})\ \ Max(R_{12},R_{22},\ \ldots,R_{i2})\ldots Max\ (R_{1j},\ R_{2j}\ ,,\ R_{ij})].$

8. Defuzzification, i.e., conversion of fuzzy values into numeric values. In this regard, the following formula is used:

$$V(t)=\frac{\sum_{j=1}^{J}\mu_t\left(u_j\right)\cdot u_{or.}^{j}}{\sum_{j=1}^{J}\mu_t\left(u_j\right)}$$

Here, $V\ (t)$ is the expected population growth for year t, $\mu_t(u_j)$ – value of the membership function calculated for the forecast year; $u^j_{or.}$ –average value of intervals, J - number of variation intervals (3, 5, 7, etc.).

The application of the proposed technique in forecasting demographic indicators (total population, able-bodied population, economically active population, births, deaths, different age groups) of the population in Azerbaijan is described. The method is tested retrospectively, and the number of the population is calculated for the future after concluding about the feasibility of using this model in the demographic forecast. The relative error of the proposed method (based on the retrospective analysis of the general population forecast for years 2002–2015) is 1.66% (error rate in the demographic prediction is 7–8%). Compared to the relative errors of the prediction results of other approaches, this method is used as an alternative approach to short- and medium-term forecasting. Relevant algorithm and software tool are developed on the basis of the proposed technique, and an intelligent demographic forecasting system (IDFS) is built. The system is implemented in the Delphi 7 programming system. The system provides predictive estimates for various demographic indicators for any year or for coming years. Fig. 2 depicts the estimated values for years of 2018–2034.



Years	Male	Female	Total
2018	4949200	4966600	9915800
2019	5006400	5013500	10019900
2020	5063000	5060000	10123000
2021	5119500	5106200	10225700
2022	5175700	5152200	10327900
2023	5231700	5198100	10429800
2024	5287400	5244000	10531400
2025	5342900	5289900	10632800
2026	5398200	5335800	10734000
2027	5453300	5381700	10835000
2028	5508300	5427600	10935900
2029	5563200	5473500	11036700
2030	5618100	5519400	11137500
2031	5673000	5565300	11238300
2032	5727900	5611200	11339100
2033	5782800	5657100	11439900
2034	5837700	5703000	11540700

Figure 2. Software window IDFS that shows the estimated values for years of 2018–2034 respectively

The IDFS functional scheme includes the following blocks (Fig. 3) [38].

Knowledge base consists of the rules formed as a result of expert knowledge processing. The part “if” in the production rules "If, then" corresponds to a certain fact revealed from the analytics of the forecast results, and the part “then” can be any decision or measure to be taken in accordance with the appropriate demographic policy.

If the condition of the Rule coincides with any fact received from the analytics block, then the Rule is enabled, the second part “then” enters the decision making block and is presented to the user as a valid decision and stored in the DB.

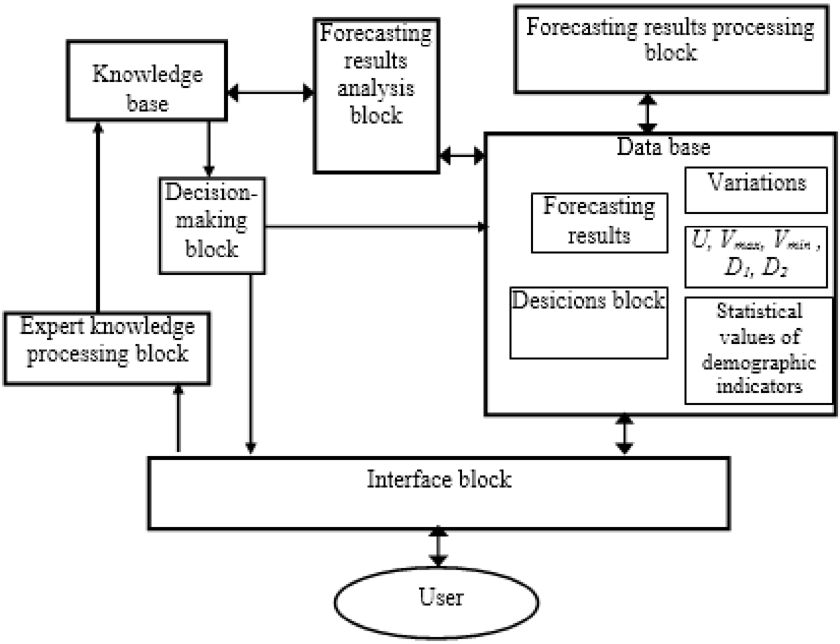


Figure 3. IDFS functional scheme

> ***Rule 1****. If there is a persistent gender bias in the projected number of births (usually female's decline, male's growth), then the gender structure of the population will be changed and measures to prevent gender bias should be taken.*

The procedure for obtaining a result (decision) according to Rule 1 is as follows:

Let the first forecast year of birth by gender to be *t*, *Q (t)* - the number of females born in the first forecast year, and *O(t)* - the number of males born in the first forecast year. In this case, the rule is formulated using the following condition operator:

*"**If** (Q (t) / O (t) > Q (t + 1) / O (t + 1) > Q (t + 2) / O (t)…),* ***then*** *the measures should be taken to prevent gender bias".*

This chapter proposes a method for prediction and planning of decision support in shaping the country's promising employment policies and achieving the condition aimed at addressing unemployment in LM based on a comprehensive approach to all the factors affecting the LM, such as economic, political, social, demographic, and other factors. In this regard, it is referred to the AHP and multi-scenario approach [3].

The prospective status of LM as a problem object is decomposed and all the indicators, factors and specific features that determine the real situation are explored through the analysis of decomposition elements. The model of LM, described as a multilevel integrated system, is illustrated in Figure 4.

As the scheme shows, the hierarchical structure of the expected situation of LM is divided into several levels, each of which has its own specific functions and content affecting the course of the situation differently:

Level 1 determines the overall objective of the study case through the perspective situation of LM, which naturally refers to the *elimination of unemployment*;

Level 2 includes the key (basic) factors that influence the achievement of the specified goal, i.e. desired status of LM;

Level 3 includes the subjects operating in LM and affecting its perspective status;

Level 4 specifies the purpose of the key LM entities.

The hierarchical model allows for the analysis of the LM’s status on multivariate scenarios and for the selection of the scenario that will dominate the future scenarios, taking into account the current LM situation. The dissertation work considers 6 different scenarios in accordance with the alternative options of perspective status of LM in Azerbaijan.

Problem statement. Assume that the hierarchical model for planning the desired status of LM is presented. It is required to develop a method for assessing the priority of possible scenarios to achieve the desired status of LM.

Problem solution is implemented in the following stages:

Stage 1. Determination of the impact of factors on the future status of LM.

Stage 2. Determination of the impact of the subjects on factors.

Stage 3. Determination of the relative importance of the goals in relation to the subjects.

Stage 4. Determination of the importance of the subjects *(Level 3)* in relation to the impact on factors.

Stage 5. Determination of important LM entities.

Stage 6. Determination of the impact of possible scenarios on the goals of the subjects.

Stage 7. Determination of the final priorities vector.

Stage 8. Analysis of final priorities vector and its appropriate interpretation.

This chapter develops a method for evaluating the effectiveness of LM by referring to a hierarchically structured criteria system and a fuzzy relational model that characterizes the effectiveness of LM [5].

According to fuzzy relational model of knowledge representation, if $X = \{x_i, i = \overline{1, n}\}$ is a set of alternatives, which are the subject to estimation and ranging, and $K = \{k_j, j = \overline{1, m}\}$ is a set of criteria characterizing these alternatives, the satisfaction degree of alternative x_i to k_j is represented by criterion membership function, i.e.: $\varphi_{k_j}(x_i) : X \times K \to [0,1]$.[5]

The main policy measures taken by the government to combat the poverty are strengthening the social protection of families with more material needs, reducing poverty, and determining the social assistance through developed methods in accordance with the real needs of citizens. Solution of these issues requires a clear choice of the subject, the implementation of fair and equal social assistance, as well as the determination of the family income.

[5] Мамедова М.Г. Принятие решений на основе баз знаний с нечеткой реляционной структурой. Баку: Элм, 1997, 296 с. (р.47)

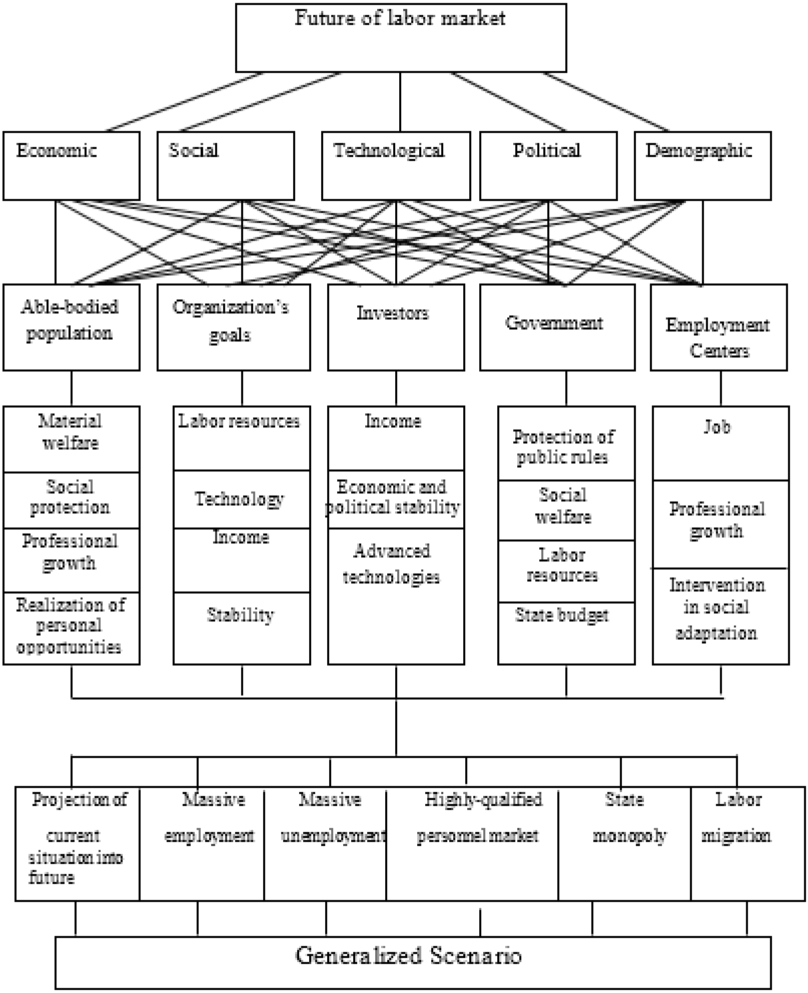


Figure 4. Hierarchical structure of labor market planning

Based on the proposed technique, the priority of the options describing the future state of the labor market in Azerbaijan is evaluated.

Family income is characterized by numerous factors and criteria that determine its level, composition and structure as a modeling object. In the Poverty Reduction System, a family income estimation method is proposed, which is based on a fuzzy relational model of knowledge description that allows to take into account the fuzziness and boundaries of the criteria to make decisions according to the real income level of each family [4, 33].

Let's give a formal **problem statement**. Let $X = \{x_i, i = \overline{1,n}\}$ - in this case, as alternative variants are considered the families applying for reception of the targeting social assistance, in which family income is characterized by set of in equivalent criteria: $K = \{K_j, j = \overline{1,m}\}$.

Each criterion K_j, which is included in a set of criteria K, in turn, is characterized by subset of special criteria, i.e. $K_j = \{k_{jt}, t = \overline{1,T}\}$, and the elements of these subsets are also inequivalent.

The purpose of the problem is reception of the systematized list of the individual conclusions on family cumulative income, ranged from worse to best according to the results of carried out family income estimation: $X : K \to X^*$, where X^* is a systematized list of the families applying for reception of the addressing social assistance.

The method of family income estimation is reduced to performance of the following steps:

1. By means of aggregation of sub-criteria (parameters) of underlying level, each criterion of top level, i.e. if $\varphi_{kjt}(x_i)$ is a membership function of alternative x_i to special criteria k_{jt} and w_{jt}, $t = \overline{1,T}$ factors of relative importance of these sub-criteria then construction of convolution of these inequivalent special criteria determines the membership function of alternative x_i to generalized criterion K_j is estimated:

$$\varphi_{K_j}(x_i) = \sum_{t=1}^{T} w_{jt}\ \varphi_{k_{jt}}(x_i). \qquad (1)$$

2. Membership function of alternative x_i to generalized criterion K is determined:

$$\varphi_K(x_i)=\sum_{j=1}^{m} w_j \varphi_{K_j}(x_i). \quad (2)$$

Where w_j, $j=\overline{1,m}$ is the corresponding factor of relative importance of criterion K_j $j=\overline{1,m}$.

3. The alternative having the minimal grade of membership to generalized criterion K is chosen:

$$\varphi(x^*)=\min\left\{\varphi_K(x_i),\ i=\overline{1,n}\right\}. \quad (3)$$

The chosen alternative is best suited to the family with the lowest income (highest poverty, the poorest among the alternatives).

The proposed mathematical model collects and considers the expert knowledge about family composition and income, which allows for assessment of family income and scientifically sound decision support to assist them, also helps to clarify the poverty rate, which can be used to support government interventions to reduce poverty.

Chapter 3 analyzes the HRM issues that require intellectual support at micro level, i.e., in the organization: recruitment, attestation, awarding, promotion, etc. The following features, which characterizes the given issues as poorly structured fuzzy environment decision making issue, are identified [2, 6, 13]:

- PM issue in the organization is a multi-criterial assessment issue;
- criteria in these issues and the sub-criteria that characterize them are both quantitative and qualitative;
- unambiguous determination of criteria is difficult, and their variation boundaries are highly variable;
- some of the criteria are defined by multiple sub-criteria that characterize them, i.e. the criteria are hierarchical (figure 5);
- the difference between the relative importance and significance of the criteria that characterize the object evaluated in PM issues

requires the consideration of their relative importance and weight;

- experts should be involved as a data carrier (source) in the determination of criteria;
- linguistic expressions of our natural language should be formalized in relation to uncertainty in the evaluation of quality criteria;
- collective decisions should be made by several experts, and the decision maker (DM) may differently evaluate the professionalism of the experts.

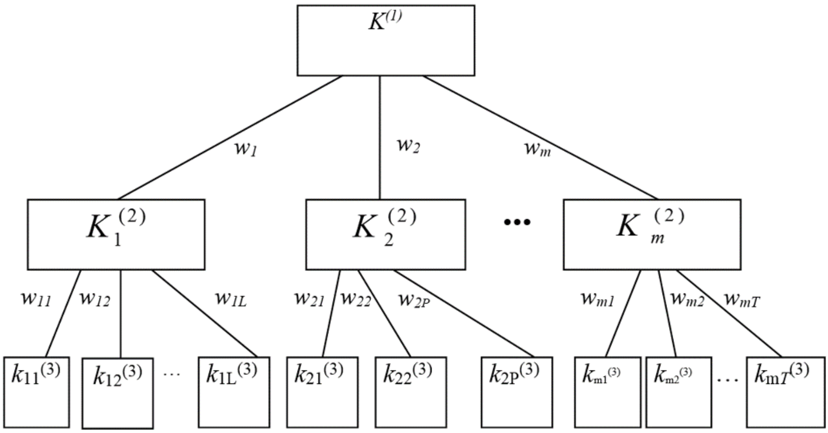


Figure 5. Hierarchal structure of selection criteria that characterize alternatives

Generalized evaluation criterion $K^{(1)}$ of the evaluation object of HRM issue that require intellectual support is defined based on m number of criteria at Level 2: $K^{(1)}=\{K_j^{(2)},\ j=\overline{1,m}\}$, and these criteria are also characterized by multiple sub-criteria: $K_j^{(2)}=\{k_{jt}^{(3)}, t=\overline{1,T}\}$.

In this case, each upper-level criterion is based on the aggregation of the sub-criteria closest to it, and the decision-making issue is brought to the evaluation of the generalized criteria.

Decision methods based on a fuzzy relational model, additive and multiplicative aggregation[6], modified TOPSIS[7] and AHP[8] are proposed, taking into account the hierarchical structure of the criteria for the solution of HRM issues discussed in this chapter [12, 13, 15].

In HRM issues that require intellectual support (recruitment, awarding, etc.), the formal formulation and solution of decision methods based on additive and multiplicative aggregation taking into account a fuzzy relational model representing the membership of the alternatives in hierarchically structured criteria and the nature of the requirements ("optional" or "mandatory") of DM are as follows.

Problem statement: Assume that:

1. $X = \{x_i, i = \overline{1,n}\}$ – set of evaluated alternatives (candidates for specific vacancies, employers nominated for awards, etc.);

2. $K = \{K_j, j = \overline{1,m}\}$ – set of criteria characterizing the alternative;

3. $K_j = \{k_{jt}, t = \overline{1,T}\}$ – set of evaluable sub-criteria characterizing each criteria (may be "optional" or "mandatory" in accordance with DM’s requirement);

4. $\{\varphi_{k_{jt}}(x_i), t = \overline{1,T}, j = \overline{1,m}\}$ – membership function of alternatives to sub-criteria $\{k_{jt}, t = \overline{1,T}, j = \overline{1,m}\}$;

5. $\{w_j, j = \overline{1,m}\}$ – coefficients of criteria’s relative importance and $\sum_{j=1}^{m} w_{jt} = 1$.

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[6] Neumann J.V., Morgenstern O. Theory of games and economic behavior. One of Princeton University presses. Notable Centenary Titles, 2007, 776 p. (pp.24-29).
[7] Kelemenis A., Ergazakis, K., Askounis D. Support managers' selection using an extension of fuzzy TOPSIS // Expert Systems with Applications, 2011, vol. 38, no. 3, pp. 2774–2782.
[8] Саати Т.Л. Принятие решений. Метод анализа иерархий. Пер. с англ. М.: Радио и связь, 1993, 320 с. (pp/9-25).

6. $\{w_{jt}, t=\overline{1,T},\ j=\overline{1,m}\}$ – coefficients of sub-criteria's relative importance and $\sum_{t=1}^{T} w_{jt} = 1$.

The goal is to find the best solution and a customized list of alternatives based on the determination of the membership of each alternative to the generalized criterion *K*.

Problem solution. If the sub-criteria characterizing the issue are desirable, then the solution to the problem is based on the following stages:

Stage 1. Based on formula (1), membership function of the alternative to criteria *Kj* is calculated (Table 1).

Table 1. Membership function of alternative to criteria K_j, $\{j=\overline{1,m}\}$

Alternatives	*K*						
	K_1			…	K_m		
	κ_{11}	…	κ_{1L}		κ_{m1}	…	κ_{mT}
x_1	$\varphi_{k_{11}}(x_1)$	…	$\varphi_{k_{1L}}(x_1)$	…	$\varphi_{k_{m1}}(x_1)$	…	$\varphi_{k_{mT}}(x_1)$
…	…	…	…	…	…	…	
x_i	$\varphi_{k_{11}}(x_i)$	…	$\varphi_{kL}(x_i)$	…	$\varphi_{k_{m1}}(x_i)$	…	…
…	…	…	…	…	…	…	$\varphi_{k_{mT}}(x_i)$
x_n	$\varphi_{k_{11}}(x_n)$	…	$\varphi_{k_{1L}}(x_n)$	…	$\varphi_{k_{m1}}(x_n)$	…	…
							$\varphi_{k_{mT}}(x_n)$

$\varphi_{K_1}(x_i),\ i=\overline{1,n}$ $\qquad$ $\varphi_{K_M}(x_i),\ i=\overline{1,n}$

Stage 2. Based on formula (1), membership function of alternative x_i to generalized criterion *K* is determined (Table 2).

Stage 3. The alternative with the highest value is selected:

$$\varphi(x^*) = \max\{\varphi_K(x_i), i=\overline{1,n}\} \quad . \tag{4}$$

Table 2. Membership function of alternative x_i to generalized criterion *K*

Alternatives	*K*				
	K_1	…	K_j		K_m
x_1	$\varphi_{K_1}(x_1)$	…	$\varphi_{K_j}(x_1)$	…	$\varphi_{K_m}(x_1)\cdots$
…	…	…	…	…	$\varphi_{K_m}(x_i)$
x_1	$\varphi_{K_1}(x_i)$	…	$\varphi_{K_1}(x_i)$	…	…
…	…	…	…	…	$\varphi_{K_m}(x_n)$
x_n	$\varphi_{K_1}(x_n)$	…	$\varphi_{K_j}(x_n)$	…	

$\varphi_K(x_i),\ i=\overline{1,n}$

The chosen alternate is the “best” one out of a large number of alternatives, and is rated first in the list adjusted for the value of the membership function of the generalization criterion *K*.

If sub-criteria characterizing the problem are mandatory, then solution of the problem is based on the multiplicative aggregation in the following stages:

Stage 1. Membership function of alternative to criteria *Kj* is calculated:

$$\varphi_{K_j}(x_i)=\prod_{t=1}^{T}\left[\varphi_{k_{jt}}(x_i)\right]^{w_{jt}} .$$

Stage 1. Membership function of alternative to generalized criterion is determined:

$$\varphi_K(x_i)=\prod_{j=1}^{m}\left[\varphi_{K_j}(x_i)\right]^{w_j} .$$

Stage 3. Based on formula (4), the alternative with the highest value of the membership function to the generalized criteria *K* is chosen out of all the alternatives.

This approach allows the alternatives to be "filtered" according to "mandatory" criteria.

In the dissertation, a multi-criteria ranking method allowing for collective decision-making taking into account the competence of the experts and the hierarchical structure and different importance rates of the criteria characterizing the alternatives based on TOPSIS modification and AHP, is developed [17, 20].

The main idea of the TOPSIS method is that the most preferable alternative should have the shortest distance from the ideal solution and the longest geometric among all alternatives from the inadmissible solution. In order to implement this method, one should handle linguistic variables and their values that express verbal ranking scales for measuring attributes. Here, the levels are arranged in the order of ascension of these attributes' intensity. In this case, the number of linguistic variables' values (ranks) is seven. Fig.6 shows a graphical representation of the transformation of linguistic values into numeric equivalents.

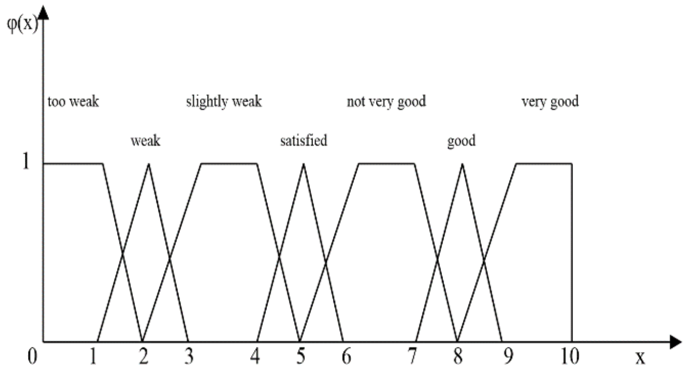

Figure 6. Transformation of linguistic values into fuzzy trapezoidal numbers

Table 3 shows the 7-level values of the linguistic variable and respective fuzzy trapezoidal numbers.

Table 3. Linguistic values and their respective fuzzy trapezoidal numbers

Linguistic values	Fuzzy trapezoidal numbers
too weak	(0,0,1,2)
weak	(1,2,2,3)
slightly weak	(2,3,4,5)
satisfactory	(4,5,5,6)
not very good	(5,6,7,8)
good	(7,8,8,9)
very good	(8,9,10,10)

Thus, a multi-criteria optimization technique is proposed for ranking the alternates in the set $X \times K \times Z$ referring to the TOPSIS modification and IAM, and assume that the followings are known:

1. $X = \{x_i,\ i = \overline{1, n}\}$ –set of admissible alternatives;

2. $K = \{k_j,\ j = \overline{1, m}\}$ – set of choice criteria that characterize alternatives;

3. $k_j = \{k_{jt}, t = \overline{1, s}\}$ – set of sub-criteria that characterize each criterion;

4. $E = \{e_l, l = \overline{1, g}\}$ – group of experts;

5. $w_j,\ j = \overline{1, m}$ – coefficients of criteria's relative importance $K = \{k_j,\ j = \overline{1, m}\}$;

6. $w_{jt}, t = \overline{1, s}_j\ , j = \overline{1, m}$ – coefficients of sub-criteria's relative importance $k_j = \{k_{jt}, t = \overline{1, s_j}\}$;

7. $v_l, l = \overline{1, g}$ – experts' competence coefficients.

Assume $f(x)$ - objective function that guarantees the choice of the best alternatives:

1) $f(x) = \max(f(x_1),\ f(x_2),..., f(x_n))$ and $f(x) \to [0,1]$,

where $f(x_i)$ is the resultant vector of the evaluation of alternative $x_i \in X$ in accordance with integral criterion K, i.e. $f(x_i) \to K(x_i)$.

2) $K(x_i) = (p(x_i), w, v)$ - integral evaluation of alternative x_i, according to the set of evaluation criteria, the weight of sub-criteria in the integral criterion K and the coefficient of the relative importance of experts' competence, where

- $p(x_i)$ integral evaluation of alternative x_i, $i = \overline{1,n}$ in accordance with the values of the linguistic variable by the experts' preference;

- $w = (w_1,..., w_Z)$ weights of sub-criteria in the integral criterion K, $z = \overline{1,Z}$. Z is the total number of sub-criteria;

- $v = (v_1,..., v_g)$ coefficient of the relative importance of experts' competence, according to the decision-maker's preferences.

3) $f(x_i) > 0,$ provided that $p(x_i) > 0$.

4) $g(K(x), w, v) \in G,\ x \in X$

4) $w_j > 0,\ j = \overline{1,m},\ \ \sum_{j=1}^{m} w_j = 1.$

5) $w_{jt} > 0,\ t = \overline{1,s_j},\ \ \sum_{t=1}^{s_j} w_{jt} = 1.$

6) $w_z > 0,\ z = \overline{1,Z}.$

7) $v_l > 0,\ l = \overline{1,g},\ \sum_{l=1}^{g} v_l = 1.$

The goal of problem is to rank the alternatives by choosing the alternative with the highest value.

The proposed method is performed on the following algorithm:

Step 1. Based on AHP, by relative importance coefficients of criteria $\{K_j,\ j=\overline{1,m}\}$ and sub-criteria $\{k_{jt},\ t=\overline{1,s_j}\}$ with which the latter will enter the calculation of the integral criterion *K*. In a formalized form, w_{jt}^K – the weight of the sub-criterion k_{jt} in the calculation of the integral criterion $K=\{k_j,\ j=\overline{1,m}\}$, i.e. $w_{jt}^K = w_{jt}\cdot w_j$ is determined by the multiplication w_j, where $\sum_{j=1}^{m} w_j = 1$, and w_{jt}, where $\sum_{t=1}^{s_j} w_{jt} = 1$. During subsequent steps, all sub-criteria are united into a single G set, with a view to simplifying indexes.

$$G=\{k_{jt},\ j=\overline{1,m}, t=\overline{1,s_j}\}=\{k_z,\ z=\overline{1,Z}\},$$

$$z=s_{j-1}+t,\ j=\overline{1,m},\ \ t=\overline{1,s_j},\ \ s_0=0.$$

Here, Z is the overall number of sub-criteria that characterize alternatives, i.e. $Z=\sum_{j=1}^{m} s_j$. In this case, $w_z = w_{jt}^K$.

Step 2. The level of membership (relation) of alternatives to sub-criteria is evaluated by linguistic values (see Table 1) and expressed by trapezoidal numbers $R^l=(r_{iz}^l)=(a_{iz}^l, b_{iz}^l, c_{iz}^l, d_{iz}^l)$. The expert evaluation of alternatives' membership to sub-criteria results in the following matrix: $R^l=\left[r_{iz}^l\right] \Leftrightarrow \{a_{iz}^l,\ b_{iz}^l,\ c_{iz}^l,\ d_{iz}^l\},\ l=\overline{1,g}$.

Step 3. The matrix

$$R^{v_l}=\left[r_{iz}^{v_l}\right], l=\overline{1,g} \Leftrightarrow \{a_{iz}^{v_l},\ b_{iz}^{v_l},\ c_{iz}^{v_l},\ d_{iz}^{v_l}\}, l=\overline{1,g} \qquad (5)$$

is formed, taking into account the experts' competence coefficient $v_l,\ l=\overline{1,g}$.

Step 4. This step determines the single aggregated matrix:

$$R^{v_l}=\left[r_{iz}^{v_l}\right] \Leftrightarrow \{a_{iz}^{v_l},\ b_{iz}^{v_l},\ c_{iz}^{v_l},\ d_{iz}^{v_l}\}, l=\overline{1,g} \Rightarrow R_{ijt}=\left[r_{iz}\right] \Leftrightarrow \{a_{iz},\ b_{iz},\ c_{iz},\ d_{iz}\} \quad (6)$$

Step 5. The elements of matrix $R_{iz} = [r_{iz}] \Leftrightarrow \{a_{iz}, b_{iz}, c_{iz}, d_{iz}\}$ are multiplied by the weights of sub-criteria. This operation builds the weighed fuzzy matrix:

$$R_{iz}^{w} = [r_{iz}^{w}] \Leftrightarrow \{a_{iz}^{w}, b_{iz}^{w}, c_{iz}^{w}, d_{iz}^{w}\}. \qquad (7)$$

Step 6. The obtained matrix is normalized:

$$R_{iz}^{N} = [r_{iz}^{N}] \Leftrightarrow \left[\frac{r_{iz}^{w}}{\max\limits_{i} r_{iz}^{w}}\right] = \left[\frac{r_{iz}^{w}}{r_{z}^{w+}}\right] = \{a_{iz}^{N}, b_{iz}^{N}, c_{iz}^{N}, d_{iz}^{N}\}. \qquad (8)$$

Step 7. The positive ideal (optimal) solution (PIS) X^{+} is determined.

$$X^{+} = [r_{z}^{+}] = (r_{1}^{+}, r_{2}^{+}, ..., r_{Z}^{+}) = (\max_{i} r_{i1}^{N}, \max_{i} r_{i2}^{N}, ..., \max_{i} r_{iZ}^{N}). \qquad (9)$$

Step 8. The negative (worst) ideal value (NIS) X^{-} is calculated.

$$X^{-} = [r_{z}^{-}] = (r_{1}^{-}, r_{2}^{-}, ..., r_{Z}^{-}) = (\min_{i} r_{i1}^{N}, \min_{i} r_{i2}^{N}, ..., \min_{i} r_{iZ}^{N}). \qquad (10)$$

Step 9. The distance of alternatives from PIS are calculated.

$$D^{+}(x_i) = \sqrt{\sum_{z=1}^{Z} (D_{z}^{+}(x_i, X^{+}))^2} \;. \qquad (11)$$

Here

$$D_{z}^{+}(x_i, X^{+}) = \sqrt{\frac{1}{4}((a_{iz}^{N} - a_{z}^{+})^2 + (b_{iz}^{N} - b_{z}^{+})^2 + (c_{iz}^{N} - c_{z}^{+})^2 + (d_{iz}^{N} - d_{z}^{+})^2)} \qquad (12)$$

Step 10. The distance of alternatives from NIS are calculated for the individual values of each sub-criterion

$$D^{-}(x_i) = \sqrt{\sum_{z=1}^{Z} (D_{z}^{-}(x_i, X^{-}))^2} \;. \qquad (13)$$

Here

$$D_{z}^{-}(x_i, X^{-}) = \sqrt{\frac{1}{4}((a_{iz}^{N} - a_{z}^{-})^2 + (b_{iz}^{N} - b_{z}^{-})^2 + (c_{iz}^{N} - c_{z}^{-})^2 + (d_{iz}^{N} - d_{z}^{-})^2)} \qquad (14)$$

Step 11. The integral indicator (proximity coefficient) is calculated:

$$D(x_i) = D^+(x_i) + D^-(x_i)$$
$$\varphi(x_i) = \frac{D^-(x_i)}{D(x_i)}. \tag{15}$$

The value of the proximity coefficient $\varphi(x_i)$ allows ranking the alternatives.

This chapter gives an overview of how to analyze and process primary information in addressing HRM issues. In this regard, the followings are implemented [10, 11]:

- mathematical description of criteria;
- determination of the relative importance coefficients of criteria;
- detailed analysis of the methods for checking for unanimity and identifying the contradiction in expert evaluations.

Chapter 4 presents the mechanisms for developing the tools and HRM decision techniques at micro-level, i.e. in the organization. It highlights the need for the evaluation of employees' performance to make decisions regarding their attestation, rewarding, motivation, promotion and reappointment in the organization.

To support the decisions on the management of the personnel engaged in scientific and technical activity, as a research object, the assessment of their labor activity is solved by the following algorithm [37]:

1) formation of the structural scheme of the evaluation system, namely, the alternatives: the list of employees, whose activity is evaluated, the evaluation criteria system, imposed restrictions and objectives;

2) selection of methods for the acquisition (selection of experts, expert evaluation, selection of quantitative and qualitative levels of criteria) and processing (mathematical representation of criteria, determination of relative importance coefficient of criterion) of initial information;

3) selection of a method that enables an integral evaluation of the results for the criteria out of certain evaluation set. Development of the algorithms and appropriate software with the reference to formulas (1), (2), (4).

Based on the proposed technique, the functional scheme of decision support system for the assessment of the activity of scientific employees at the Institute Information Technology of ANAS and their rewarding, promotion and re-deployment based on the evaluation results is illustrated in Fig. 7 [37].

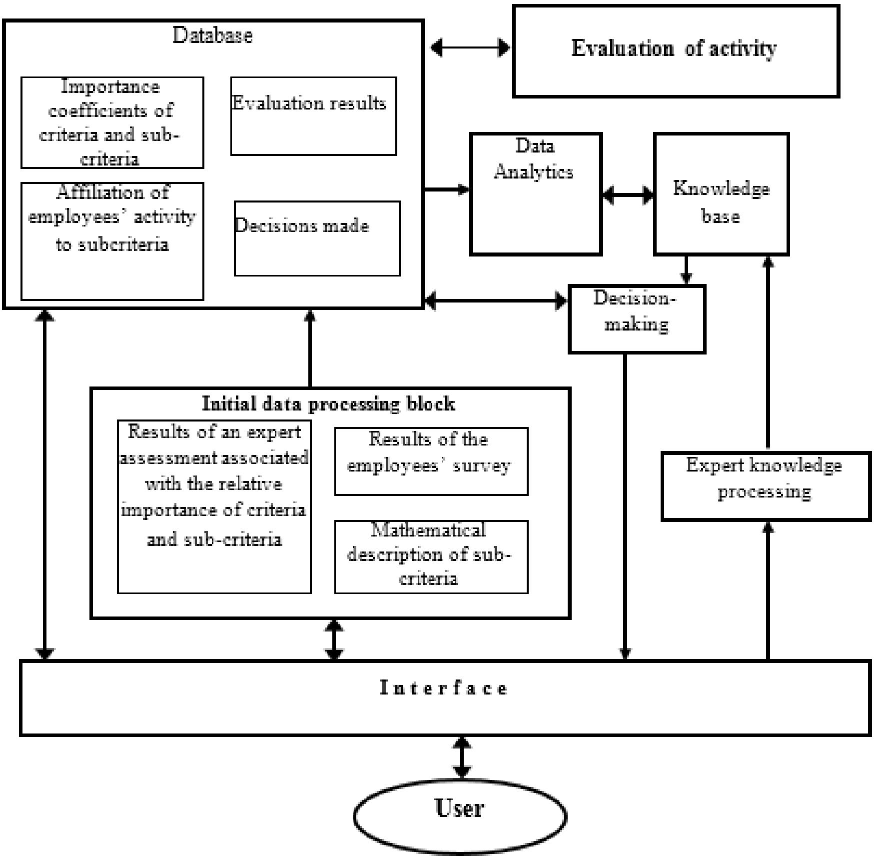

Figure 7. Functional scheme of decision support system for the assessment of the activity of scientific employees

Knowledge base consists of the rules representing the managerial decisions in accordance with the affiliation of the employees' activity to criteria (or sub-criteria) and summarizing criterion. The first part of the production rules, which are based on expert knowledge and described as “if …, then …”, corresponds to the specific fact based on the values of the criterion (or summarizing criterion, sub-criteria) that characterizes the activity for a particular decision. Whereas the “result” represents the management decision appropriate to the same fact. The rules for staff rewarding are based on the proposed limits related to the amount of the award. It should be noted that the amount of award to be presented to the employees corresponds to the linguistic values on 4 levels, as "very high, high, medium, low". In this case, the rules for awarding can be described as follows:

Rule 1. If $\varphi_K(x_i) \in [0.9,\ 1]$*, then the employee may be awarded a "very high" award;*

Rule 2. If $\varphi_K(x_i) \in [0.75, 0.9)$*, then the employee may be awarded a "high" award;*

Rule 3. If $\varphi_K(x_i) \in [0{,}60,\ 0.75)$*, then the employee may be awarded a "medium" award;*

Rule 4. If ($\varphi_{K_1}(x_i) \in [0.00,\ 0{,}30]$ *and* $\varphi_{k_{33}}(x_i) \geq 0{,}75$ *and* $x_i \in S_S$ *), then the transfer of an employee to the training department can be viewed;*

Rule 5. If ($\varphi_K(x_i) \in [0.00,\ 0{,}30]$ *and* $\varphi_{k_{51}}(x_i) \in [0{,}0 - 0{,}5)$*), then this employee can be warned about the wage and execution discipline* and etc.

Here, K is the generalizing criterion of labor activity, K_1 - a criterion for scientific-theory activity, k_{33} – training the graduate students and masters, k_{51} - a sub-criterion for labor discipline, and S_s represents a department engaged in scientific and theoretical activities.

This chapter develops a solution algorithm based on a multi-criteria ranking method with reference to TOPSIS modification and AHP to assess and rank the candidates to be employed in large organizations, and the problem is implemented in the following steps [20, 30]:

1. Formalization of a criteria system and alternatives. It is supposed to find $\varphi(x_i)$ defined in the range of [0.1] of the recruitment opportunities as the result of the one-digit evaluation of the alternatives.

2. Formulation of possible final decisions.

Assume that the following decision options related to employment are formed:

- *If* $\varphi(x_i) \in [0, 0.25)$, *the candidate obviously does not conform to the requirements of the position, i.e. the candidate is turned down;*
- *If* $\varphi(x_i) \in [0.25, 0.45)$, *the candidate weakly conforms to the requirements of the position, therefore, his/her recruitment poses high risk.*
- *If* $\varphi(x_i) \in [0.45, 0.65)$, *the candidate partially (to a certain extent) conforms to the requirements of the position. The recruitment of the candidate poses low risk, which can be compensated for by high indicators in other competencies during work;*
- *If* $\varphi(x_i) \in [0.65, 0.85)$, *the candidate conforms to the requirements of the position, while certain indicators can be easily improved during adaptation;*
- *If* $\varphi(x_i) \in [0.85, 1)$, *the candidate fully conforms to the requirements of the position.*

3**.** Calculation of the coefficients of criteria’s relative importance based on pairwise comparison, forming the expert group, and detection of contradictions in expert evaluations**.**

4. Calculation of the coefficients of the competence of experts.

5. Evaluation of the candidates for the level of membership to sub-criteria based on linguistic variables (for example, 7-level provided in table 3).

6. Building a generalized matrix of fuzzy trapezoidal numbers based on the evaluations of experts.

7. Determination of the proximity of the applicants to the ideal solution based on formulas (5) - (15).

Based on the proposed technique, the evaluation of the applicants to be recruited to the HRM department is implemented in the framework of the Grant SOCARET 2013 project. A system of criteria for the evaluation of 3 applicants and the coefficients based on their pairwise comparisons are shown in Table 4 [30]. The distances from each alternative to PIS and NIS are presented in Table 5.

Table 4. Coefficients of relative importance of criteria and sub-criteria, weight of sub-criteria in *K*

criteria	criteria relative importance coefficients	Sub-criteria	Sub-criteria relative importance coefficients	Sub-criteria weight coefficients
K1-Professional (education, knowledge, professional skills, abilities, etc.)	0.11	k_{11}-conformity of the education to the job requirements	0.54	0.06
		k_{12}- scientific and research abilities	0.46	0.05
K_2 – motivational	0.08	k_{21}- sense of purpose	0.47	0.04
		k_{22} result orientation	0.53	0.04
K_3 – Business	0.4	k_{31}-diligence	0.2	0.08
		k_{32}-creativity	0.22	0.13
		k_{33}-initiative	0.26	0.10
		k_{34}-self-sufficiency	0.32	0.09
K_4 – Personal	0.1	k_{41}-trainability	0.63	0.06
		k_{42}-can-do attitude	0.37	0.04
K_5 – Individual-psychological and health	0.31	k_{51}-physical health	0.35	0.11
		k_{52}-psychological resilience	0.65	0.20

Table 5. Distances of alternatives from NIS and PIS by values of each sub-criterion

Sub-criteria	X^+	X^-	$D(x_1X^+)$	$D(x_2X^+)$	$D(x_3X^+)$	$D(x_1X^-)$	$D(x_2X^-)$	$D(x_3X^-)$
k_1	(0.259,1,1,3.857)	(0.148, 0.844,0.913, 3.857)	0.016	0.10515	0.000	$D(x_1X^-)$	$D(x_2X^-)$	$D(x_3X^-)$
k_2	(0.293,1,1,4.286)	(0.233, 0.716, 0.757, 3.068)	0.03	0.58711	0.58059	0.09388	0	0.10516
k_3	(0.266,1,1,3.75)	(0.133, 0.770, 0.781, 3.068)	0.06	0.03889	0.01643	0.19216	0.016	0.05325
k_4	(0.266,1,1,3.75)	(0.233, 0.804, 0.788, 3.375)	0.24	0.000	0.21312	0	0.13669	0.25568
k_5	(0.266,1,1,3.75)	(0.133, 0.767, 0.771, 3.375)	0.26	0.016	0.20114	0	0.23721	0.19481
k_6	(0.233,1,1,4.286)	(0.162, 0.705, 0.771, 3.857)	0.48	0.0355	0.27593	0	0.25365	0.11608
k_7	(0.266,1,1,3.75)	(0.133, 0.748, 0.744, 3.375)	0.00	0.21342	0.49862	0.11609	0.147	0.03550
k_8	(0.296,1,1,3.375)	(0.259, 0.877, 0.922, 3.375)	0.20	0.18755	0.29292	0.24918	0.10053	0
k_9	(0.233,1,1,4.286)	(0.166, 0.928, 0.865, 3.857)	0.00	0.15085	0.02345	0.02	0.07283	0.02147
k_{10}	0.296,1,1,3.375)	(0.259, 0.780, 0.894, 3.375)	0.13	0.07642	0.01	0.23018	0.0335	0.22337
k_{11}	(0.266,1,1,3.75)	(0.233, 0.804, 0.787, 3.375)	0.07	0.221	0.000	0.00748	0.05190	0.11904
k_{12}	(0.296,1,1,3.375)	(0.148, 0.816, 0.853, 3.375)	0.02	0.13943	0.000	0.07684	0	0.23747

Distance of compared alternatives from PIS and NIS, the coefficient of their proximity to the ideal solution and respective ranks are presented in Table 6.

Table 6. Distance of compared alternatives from PIS and NIS, the coefficient of their proximity to the ideal solution and respective ranks

Alternatives	$D(x_iX+)$	$D(x_iX^-)$	$D(x_iX^{+)}+ D(x_iX^-)$	$\varphi_K(x_i)$	ranks
x_1	0.46847	0.44805	0,91652	0.48886	1
x_2	0.80634	0.41503	1,22137	0,33981	3
x_3	0.91326	0.52174	1,43500	0.36358	2

The proposed method can be applied to different areas of multi-criterial evaluation, selection and ranking, taking into account the competence ratios of the experts, the hierarchical structure of the criteria and the coefficients of importance, without limiting the number of alternatives and criteria and the number of experts involved in the assessment.

This chapter shows that the dynamics of development of the ICT sector results in the increasing demand for IT specialists, the frequent changes, dynamics and instability of the requirements set out in the process of their recruitment [8]. These have led to the development of mechanisms for to manage the labor market of IT specialists based on fuzzy input data [18, 19, 29]. Taking into account all of these, the methods are developed to support the decision-making process of employers (DMs) to manage the hiring process of IT professionals, taking into account the requirements for meeting the criteria [9, 14, 26].

In terms of the employers' requirements, in accordance with the formalization of the problem of employment of IT professionals, $X = \{x_i, i = \overline{1, n}\}$ are the alternatives, i.e. applicants for a vacancy (rather, forming a supply base), $K = \{k_j, j = \overline{1, m}\}$ - a set of criteria (e.g., competitors' knowledge, abilities and personal qualities), and $k_j = \{k_{jt}, t = \overline{1, s}\}$ - sub-criteria. DM specifies his/her requirements for holding a specific position by means of value related to the obligatory (O), desirability (D), and unimportance (U) of sub-criteria $\{k_{jt}, t = \overline{1, s}, j = \overline{1, m}\}$ representing the "vacancy portrait", that is, he/she shapes the base of requirements describing the portrait of the IT specialist sought.

Objective of the issue is to select the best alternative from the supply base in accordance with demand base for occupation of a specific vacancy or make a ranked list of alternatives from best to worst : $X : K^* \to X^*$. Hereby, X is a set of primary alternatives, K^* – a set of sub-criteria marked with obligation (O), desirability (D) and unimportance (U), X^* – a ranked list of selected alternatives in accordance with demand.

Modeling of the Demand Base. Employer's sub-criteria $\{k_{jt}, t = \overline{1, T}, j = \overline{1, m}\}$ for occupation of a specific vacancy are divided into three groups as obligatory (O), desirable (D) and unimportant (U) and form relevant sets: {O}, {D}, {U}.

Let's note that,

$$\{O\} \cap \{D\} \cap \{U\} = \varnothing$$

and

$$\{O\} \cup \{D\} \cup \{U\} = \{k_{jt}, t = \overline{1, s}, j = \overline{1, m}\},$$

i.e. these sets do not have a common element, any element $k_{jt} \in K_j \in K$ can belong to only one of these sets.

Following possible situations – scenarios can happen depending on distribution of sub-criteria $\{k_{jt}, t=\overline{1,s}, j=\overline{1,m}\}$ among sets {O}, {D}, {U}.

Scenario 1. All sub-criteria defining criteria K_j are obligatory: $k_{jt} \in \{O\}, t=\overline{1,s}$;

Scenario 2. A part of sub-criteria defining criteria K_j are obligatory, another part is unimportant: $k_{jt} \in \{O\} \cup \{U\}, t=\overline{1,s}$;

Scenario 3. All sub-criteria defining criteria K_j are desirable: $k_{jt} \in \{D\}, t=\overline{1,s}$;

Scenario 4. A part of sub-criteria defining criteria K_j are desirable, another part is unimportant: $k_{jt} \in \{D\} \cup \{U\}, t=\overline{1,s}$;

Scenario 5. A part of sub-criteria defining criteria K_j are obligatory, another part is desirable: $k_{jt} \in \{O\} \cup \{D\}, t=\overline{1,s}$;

Scenario 6. A part of sub-criteria defining criteria K_j are obligatory, another part is desirable and a third part is unimportant: $k_{jt} \in \{O\} \cup \{D\} \cup \{U\}, t=\overline{1,s}$;

Scenario 7. All sub-criteria defining criteria K_j are unimportant: $k_{jt} \in \{U\}, t=\overline{1,s}$.

(Let’s note that, scenario 1 and 3 do not emerge during research and scenario 6 is the most common scenario.).

Formation of the proposal base. As a result of the determination of the membership of IT-specialists to be recruited, a supply base is created, $\{\varphi_{k_{jt}}(x_i), t=\overline{1,T}, j=\overline{1,m}\}$ is a membership function of alternatives to sub-criteria $\{k_{jt}, t=\overline{1,T}, j=\overline{1,m}\}$.

Assessment of alternatives. The following multi-scenario decision method is proposed to assess the compatibility of the alternatives to the recruitments of the employers for announced vacancy in the process.

Stage 1. Membership functions are determined for the alternatives criteria in accordance with the generated scenario.

1. *Based on Scenario 1*, membership function of the alternative to criteria *Kj* is calculated using following equation.

$$\varphi_{k_j}(x_i) = \prod_{t=1}^{s} \left[\varphi_{k_{jt}}(x_i)\right]^{w_{jt}} .$$

Here $\varphi_{k_{jt}}(x_i)$ is the membership function of the job application to k_{jt} indicator, w_{jt} –importance factor *of* sub-criteria k_{jt}. Let's note that, $\sum_{t=1}^{s} w_{jt} = 1, \quad t = \overline{1, s}$ condition must be met for criteria indicators.

Based on Scenario 2: Suppose, g quantity of sub-criteria defining criteria Kj are evaluated as unimportant and naturally g<s. Then, the membership function formula of the alternative to criteria Kj (1) is defined based on s-g quantity of obligatory indicators.

$$\varphi_{k_j}(x_i) = \prod_{t=1}^{s-g} \left[\varphi_{k_{jt}}(x_i)\right]^{w_{jt}} .$$

Based on Scenario 3: Membership function of the *i-th* alternative to K_j criteria is calculated using**:**

$$\varphi_{k_j}(x_i) = \sum_{t=1}^{s} w_{jt}\, \varphi_{k_{jt}}(x_i).$$

Based on Scenario 4, membership function of *i-th* alternative to criteria K_j is found only based on formula for sub-criteria included in {D} set (2):

$$\varphi_{k_j}(x_i) = \sum_{t=1}^{s-g} w_{jt}\, \varphi_{k_{jt}}(x_i).$$

Based on Scenario 5, in order to find the membership function of *i-th* alternative to criteria K_j, first, the difference of membership function of its obligatory indicators from 0 is checked and if one of them equals to zero, then $\varphi_{K_j}(x_i)$ =0 is accepted:

$$\varphi_{k_j}(x_{\mathrm{i}}) = \prod_{t=1}^{g}\left[\varphi_{k_{jt}}(x_i)\right]^{w_{jt}} + \sum_{t=g+1}^{s} w_{jt}\cdot\varphi_{k_{jt}}(x_{\mathrm{i}}).$$

Here, $k_{jd} \in \{M\}, d = \overline{1, g}$ — K_j is the obligatory sub-criteria characterizing criteria K_j, and naturally, in this case, $g<s$.

During the solution of the problem based on *Scenario 6,* if *S* quantity of sub-criteria K_j is evaluated as unimportant, then it is possible to find the membership function of the alternative to this criterion by carrying out the operational sequence relevant with formula (3) in accordance with *s-g* quantity of sub-criteria:

$$\varphi_{k_j}(\mathrm{x_i}) = \prod_{t=1}^{g}\left[\varphi_{k_{jt}}(x_i)\right]^{w_{jt}} + \sum_{t=g+c+1}^{s} w_{jt}\cdot\varphi_{k_{jt}}(x_i),$$

Here *s–(g+c)* – is desirability sub-criteria number.

During the solution of the problem based on *Scenario 7,* during the definition of membership function of the alternative to K, (i.e. the value of the job applicant's chance to get the job), its membership function to K_j is not taken into consideration.

Stage 2. Basing on aggregation of membership functions $\{\varphi_{k_j}(x_i), \ j = \overline{1, m}\}$ according to the following formula:

$$\varphi_K(x_i) = \sum_{j=1}^{m} w_j \ \varphi_{K_j}(x_i)$$

is defined $\varphi_K(x_i), i = \overline{1, n}$ – membership functions of alternatives x_i to generalized criteria K. Here, w_j – coefficient of importance of the criteria K_j and $\sum_{j=1}^{m} w_j = 1$.

Stage 3. Obtained results are reviewed based on the rules of 3rd condition, and appropriate decision for each alternative. $\varphi(x^*) = \max\{\varphi_K(x_i), i = \overline{1, n}\}$.

The chosen alternate is the “best” alternative and ranked first in the adjusted list. The multi-scenario approach proposed for the recruitment of IT professionals also enables the selection of an employee in accordance with the specific requirements for "vacancy portrait" set forth by DM in other areas undergoing dynamic changes.

This chapter highlights the HRM decision support issue in VO, sometimes referred to as networking organizations [31, 32]. The formation of VO's human resources is determined by the involvement and recruitment of employees to VO. To solve this problem, a method for identifying the priority of alternatives is proposed, with the reference to AHP and multiplicative aggregation, pairwise criteria comparison and conflict detection criteria. The problem of assessing each employee's performance in achieving a common outcome in VO is analyzed, and it is shown that, composed of virtual workers (or virtual group), VO can be described as a system of fragmented distributed subsystems. Each of these employees has a personal purpose, but does not have enough information and resources to solve a common problem. Depending on the nature of the function performed by the virtual groups, three types of distribution are distinguished: 1) virtual groups are performing the same functions - horizontal distribution; 2) virtual groups are performing the functions of different characteristics - vertical distribution; 3) virtual groups are performing the functions of blended characteristic - blended distribution. The physical fragmentation of the needed information depends on the criteria that characterize the alternatives (employees) and the relations with the sub-criteria. Thus, the assessment of employees' performance in VO consisting of subsystems is solved by reducing the task to the decision-making task in a distributed environment [9].

Depending on the nature of the function performed by employees, the following decision-making methods are proposed.

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[9] Abbasov A.M, Mamedova M.G, Jabrayilova Z.G., Alijev E.R. Management Decision Support System on Distributed Structure // IFAC Proceedings Volumes, 1992, 25(18), pp.239-240.

1. *Workers of VO perform same functions*, that is, their activities are characterized by the same criteria.

Decision-making methods in distributed environments. The following conditions in *horizontal distribution* of Virtual Groups are ensured: $X = \bigcup_{g=1}^{G} X_{ig}$,

where X is a set of alternatives, X_{ig} - alternatives in the g-th fragment (sub-system) and $X_{ig} \cap X_{ij} = \varnothing$ and $K_g \cap K_j = K_g = K_j = K$ for $\forall$ $g \neq j$.

That is, the alternatives distributed by fragments are characterized by the same criteria. Criteria have a hierarchical structure and different weight coefficients, i.e.: $K = \left\{K_m,\ m = \overline{1, M}\right\}$, w_1, w_2, ... , w_T – are the relative importance ratios of criteria $K_m,\ m = \overline{1, M}$.

$K_m = \left\{k_{mt},\ t = \overline{1, T}\right\}$ and w_{m1}, w_{m2}, ... , w_{mT} are the relative importance ratios of sub-criteria characterizing the criterion K_m.

Assume that, in each fragment, the membership function of sub-criteria is known:

$$\left\{\varphi_{k_{m1}}\left(x_{ig}\right), \varphi_{k_{m2}}\left(x_{ig}\right), \ldots, \varphi_{k_{mT}}\left(x_{ig}\right)\right\} = \left\{\varphi_{k_{mt}}\left(x_{ig}\right), t = \overline{1, T}\right\}$$

Decision making process is performed on the following steps:

1. The membership function of alternatives to the criterion K_m in each fragment is defined:

$$\varphi_{K_m}\left(x_{ig}\right) = \sum_{t=1}^{T} w_{mt}\ \varphi_{k_{mt}}\left(x_{ig}\right)$$

2. The membership function of alternatives to the generalized criterion K in each fragment is defined:

$$\varphi_{K}\left(x_{ig}\right) = \sum_{m=1}^{M} w_m \varphi_{Km}\left(x_{ig}\right)$$

3. The maximum of alternatives by fragments is selected:

$$\varphi(x^*) = \max\left\{\varphi_K\left(x_{ig}\right),\ g = \overline{1, G},\ i = \overline{1, N}\right\}.$$

The alternative with the maximum value is the final decision on horizontally distributed virtual groups, and it is found out of set of decisions with the maximum values on fragments, i.e., $x^* \in \left\{x_{ig}^*,\ g = \overline{1, G}\right\}$.

2. *Workers of VO perform different functions*, that is, their activities are characterized by different criteria and such distribution corresponds to the distribution of vertical fragments.

The following conditions are ensured for *vertical distribution* of virtual groups: $K = \bigcup_{m=1}^{M} K_m$, where K consists of a set of criteria $K = \left\{K_m,\ m = \overline{1, M}\right\}$ with different importance degree, and M – the number of fragments (groups). $K_m = \left\{k_{mt},\ t = \overline{1, T}\right\}$ is a set of sub-criteria with different importance degree in each fragment, and w_{m1}, $w_{m2}, \ldots, w_{mT}$ are the relative importance factors of sub-criteria.

In this case, the following conditions are ensured: $K_{mg} \cap K_{mj} = \varnothing$ and $X_g \cap X_j = X_g = X_j = X$ for $\forall g \neq j$.

That is, the same alternatives for vertically distributed VO by fragments are characterized and evaluated by different criteria. Assume that membership function of the alternative x_i to the sub-criteria in the m-th fragment is known: $\left\{\varphi_{k_{m1}}(x_i),\ \varphi_{k_{m2}}(x_i),\ \ldots,\ \varphi_{k_{mT}}(x_i)\right\} = \left\{\varphi_{k_{mt}}(x_i),\ t = \overline{1, T}\right\}$.

Under these conditions, a decision method for VO distributed by vertical fragments is proposed.

Selected alternative with the maximum value corresponds to the final decision on the vertical fragments, and this decision may not be from the best decisions, i.e. from the set of fragments $\varphi_{Km}(x^*) = \max\left\{\varphi_{Km}(x_i),\ i = \overline{1, N}\right\}$.

3. Workers of VO perform blended functions, that is, in an environment where the VO is distributed by blended (both horizontally and vertically) fragments, the decision-making process can be accomplished by referencing to decision-making methods in a vertical distribution environment.

Chapter 5 analyzes the status of human resource support in meso-level, i.e. in the medical sector, and provides a review of the main indicators of medicine [36]. It highlights the impact of the integration of information technology into the medical field, the formation of electronic medicine and the trends created by the Big Data phenomenon in the medical sector and the supply and demand for the staff in this sector [22, 23, 25]. It is mentioned that, currently, in accordance with WHO initiative, to assess the supply and demand for medical personnel, it is referred to sociological survey methods and statistical methods. However, the incompleteness of statistical data in the medical field, ignoring the recent changes in their collection and processing, do not allow for an adequate picture of the medical professionals' market, and the quality aspects of supply and demand related to competencies can only be evaluated by expert assessments. In addition to sociological surveys, it is necessary to refer to scientific approaches and methods, and to develop scientifically sound management mechanisms to regulate the supply and demand for medical personnel, in order to provide human resource trainings in accordance with these requirements. Demand and supply management is examined from the point of view of medical professionals and employers, who are separate market participants. The behavioral strategies of these subjects are analyzed at the level of the medical institution [24]. At the level of the medical institution, the structure and volume of demand for medical professionals and the requirements for their professional and personal competence are specified. Therefore, the proposed scenarios in [35] and appropriate decision-making methods are developed in accordance with the multivariate compatibility of supply and demand in the medical personnel market [27, 28].

Problem statement. Assume that there are two sets of fuzzy situations describing the state of demand $\tilde{V}_i$ and supply $\tilde{S}_g$ in the medical labor market:

$$\tilde{V}_i = \left\{ < \mu_{l_{ij}}(V_i) >, < \mu_{c_{if}}(V_i) >, < \mu_{u_{i\gamma}}(V_i) > \right\} = \left\{ \mu_{V_i}(y)/y \right\}$$

$$\tilde{S}_g = \left\{ < \mu_{l_{gj}}(s_g) >, < \mu_{c_{gf}}(s_g) >, < \mu_{u_{g\gamma}}(s_g) > \right\} = \left\{ \mu_{S_g}(y)/y \right\}.$$

The set $\tilde{V}_i = \left\{ \mu_{V_i}(y)/y \right\}\ i = \overline{1,k}$ is the description of fuzzy reference situations and the set $\tilde{S}_g = \left\{ \mu_{S_g}(y)/y \right\}\ g = \overline{1,q}$ is the description of fuzzy real situations. $L = \left\{ l_j \right\}, j = \overline{1,n}$ – a set of personal features, $C = \left\{ c_f \right\}, f = \overline{1,m}$ – a set of real competences; $U = \left\{ u_\gamma \right\}, \gamma = \overline{1,p}$ – a set of preferences.

For intelligent management of demand and supply in the medical labor market, it is proposed to reduce the problem of making decision on matching demand and supply to a problem of fuzzy pattern recognition. The problem of pattern recognition is based on a fuzzy situational analysis and determination of the degree of similarity of fuzzy situations.

Problem solution. Various measures for determining the degree of similarity between two fuzzy situations including one-step or multi-step estimation procedures are discussed. In the present work, the degree of fuzzy equality is used as the measures of estimation of the degree of proximity of fuzzy real and reference situations [10]:

$$\mu(\tilde{S}_g, \tilde{V}_i) = \vee(\tilde{S}_g, \tilde{V}_i) \vee (\tilde{V}_i, \tilde{S}_g) = \&\mu(\mu_{S_g}(y), \mu_{V_i}(y)) =$$
$$= \min_{y \in Y}\left[\min(\max(1 - \mu_{S_g}(y), \mu_{V_i}(y)), \max(\mu_{S_g}(y), 1 - \mu_{V_i}(y))) \right]. \quad (16)$$

[10] Мелихов А.Н., Бернштейн Л.С., Коровин С.Я. Ситуационные советующие системы с нечеткой логикой, М.:Наука, 1990, 272 с. (p.105).

The situations $\tilde{S}_g$ and $\tilde{V}_i$ are considered fuzzy equal $\tilde{S}_g \approx \tilde{V}_i$, if $\mu(\tilde{S}_g, \tilde{V}_i) \geq \psi$ and $\psi \in [0{,}7;1]$, where ψ is some threshold of fuzzy equality of situations.

On completion of the process of recognition of the most appropriate (by the degree of proximity) pair "employer – medical specialist" among the sets of real search images of medical specialists (supply) and the reference search images of request (demand), several possible scenarios can take place:

Scenario 1. One vacancy (the employer's request) and one candidate (medical specialist).

In this case, if the degree of fuzzy similarity between two situations (16) (the reference search image of vacancy and the search image of the applicant) is not less than the threshold specified by the employer, the decision on hiring is made.

Scenario 2. In accordance with the measure of similarity between two fuzzy situations, several candidates (medical specialists) correspond to the employer’s preferences. The candidates form a subset of fuzzy situations (alternatives), out of which one must be chosen as corresponding to the most suitable candidate.

Scenario 2.1. The decision-making task is reduced to the comparison of similarity between the reference and the real-life situations by the degree of possession of the criteria characterizing the candidates for the vacancy. The best alternative (the candidate) is considered one who has the greatest degree of similarity by matching the criteria and the level of their possession.

Scenario 2.2. The decision-making task is reduced to a multi-criteria choice of the best possible solution (alternative) taking into account the relative importance of the criteria characterizing medical specialists.

Method for decision making. In this case, the task of decision-making is implemented in accordance with the following stages:

Step 1. The coefficients of relative importance of the indicators shall be defined.

Assume that: $\omega_j,\ j=\overline{1,n}$ – coefficients of relative importance of indicators characterizing the criterion *L*; $\omega_f,\ f=\overline{1,m}$ – the criterion *C*; $\omega_\gamma, \gamma=\overline{1,p}$ – the criterion *U*.

*Step 2***.** Based on the aggregation of the degrees of possession of individual indicators (i.e. $\mu_l\left(\tilde{S}_g,\tilde{V}_i\right),\ j=\overline{1,n},\quad \mu_c\left(\tilde{S}_g,\tilde{V}_i\right),\ f=\overline{1,m},\quad \mu_u\left(\tilde{S}_g,\tilde{V}_i\right),\gamma=\overline{1,p}$ the specific medical specialists determine the degree of fuzzy similarity of fuzzy real situations with the reference situation by the following step:

a) Based on the "convolution" $\mu_l\left(\tilde{S}_g,\tilde{V}_i\right),\ j=\overline{1,n},$ the degree of fuzzy similarity between real and reference situations is determined by personal characteristics (L):

$$\mu_L\left(\tilde{S}_g,\tilde{V}_i\right)=\sum_{j=1}^{n} w_j\ \mu_l\left(\tilde{S}_g,\tilde{V}_i\right).$$

b) Based on the "convolution" $\mu_c\left(\tilde{S}_g,\tilde{V}_i\right),\ f=\overline{1,m}$ – the degree of fuzzy similarity between real and reference situations is determined in terms of competences (C):

$$\mu_C\left(\tilde{S}_g,\tilde{V}_i\right)=\sum_{f=1}^{m} w_f\,\mu_c\left(\tilde{S}_g,\tilde{V}_i\right).$$

c) Based on the "convolution" $\mu_u\left(\tilde{S}_g,\tilde{V}_i\right),\gamma=\overline{1,p}$ – the degree of fuzzy similarity between real and reference situations is determined through the prism of the requirements for the vacancy U:

$$\mu_U\left(\tilde{S}_g,\tilde{V}_i\right)=\sum_{\gamma=1}^{p} w_\gamma\ \mu_u\left(\tilde{S}_g,\tilde{V}_i\right).$$

d) Based on the obtained results and coefficients of relative importance *L, C* and *U* – w_L, w_C, w_U, the similarity rates of the real situation with the reference ones are determined:

$$\mu_w\left(\tilde{S}_g,\tilde{V}_i\right)=\omega_L\cdot\mu_L\left(\tilde{S}_g,\tilde{V}_i\right)+\omega_C\cdot\mu_C\left(\tilde{S}_g,\tilde{V}_i\right)+\omega_U\cdot\mu_U\left(\tilde{S}_g,\tilde{V}_i\right).$$

Step 3. Fuzzy real situation with the maximum value is chosen:

$$\varphi\left(\tilde{S}_g,\tilde{V}_i\right)^*=\max\left\{\varphi\left(\tilde{S}_g,\tilde{V}_i\right),\ g=\overline{1,\eta}\right\}.$$

The selected fuzzy real situation corresponds to the search pattern of the applicant, who has the highest fuzzy similarity with the reference pattern of the vacancy, and is accepted as the best solution.

Scenario 2.3. The list of evaluation criteria is extended, and the input situations are re-defined (reexamined) and the recognition procedures are repeated. Block diagram of the decision-making process for scenario 2 is shown in Figure 8.

Scenario 3. Several employers are identified, who are interested in hiring one specialist, i.e. “more fuzzy reference image – one fuzzy real image”.

Scenario 3.1. The proximity rate of the claims of the medical specialist with the criteria characterizing the conditions of employment shall be compared, and decision shall be made on the greatest coincidence of the degree of possession of the criteria.

Method for decision making. The task of decision making is reduced to the comparison of the similarities between real and standard situations in terms of the similarity rate of the conditions offered by employers and the claims of the applicant. The best vacancy has the highest similarity by the coincidence of the criteria that characterize the conditions offered by employers, and the applicant’s claims. Thus, assume that:

$$\mu(\tilde{S}_d,\tilde{V}_z)=\max\left\{\mu(\tilde{S}_g,\tilde{V}_z),\ z=\overline{1,f},\ \ g=\overline{1,q}\right\}$$

$$V_z\in\left\{V_i,\ i=\overline{1,k}\right\},\qquad S_d\in\left\{S_g,\ g=\overline{1,q}\right\},\ 2\le f<k.$$

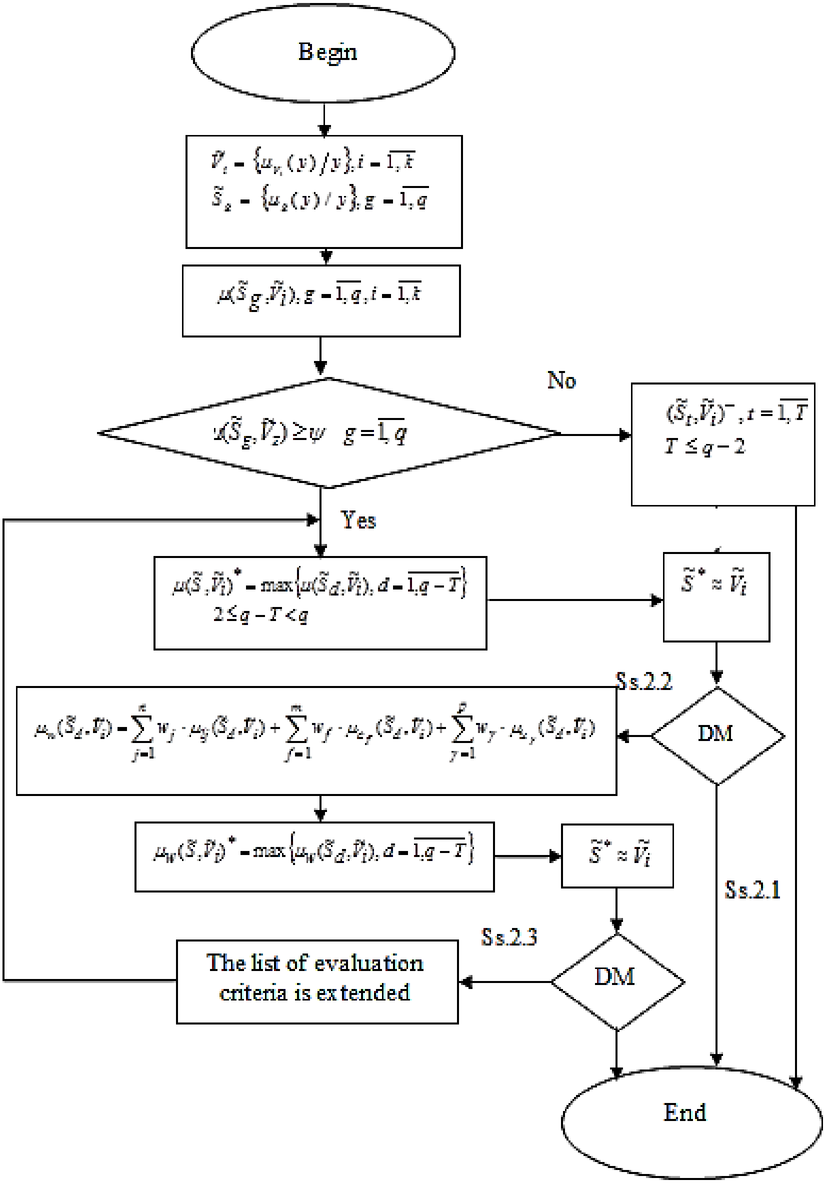

Figure 8. Block diagram of the decision-making process for scenario 2

In this case, the pair with the maximum value of the degree of fuzzy similarity situations is defined by the following formula:

$$\mu(\tilde{S}_d, \tilde{V}_\beta)^* = \max\left\{\mu_U(\tilde{S}_d, \tilde{V}_z),\, z = \overline{1,\, f}\right\}. \quad V_\beta \in \left\{\tilde{V}_z,\, z = \overline{1,\, f}\right\}.$$

The fuzzy reference situation is accepted as the best solution, which is corresponding to the search pattern of the vacancy that has the highest fuzzy similarity with the applicant's real pattern.

Scenario 3.2. The task of decisions making shall be reduced to the multi-objective task of choosing the best solution, taking into account the relative importance of the criteria that characterize workplaces.

Method for decision making. The task of decisions making shall be reduced to the multi-objective task of choosing the best solution, taking into account the relative importance of the indicators characterizing the preferences of the IT specialist (*U*), expressed in terms of his/her requirements for a IT profile vacancy.

If $\omega_\gamma, \gamma = \overline{1,\, p}$ the coefficients of the relative importance of the indicators characterizing the criterion *U*, then a fuzzy reference situation that has the greatest degree of fuzzy similarity with the applicant's real image is determined based on the following formula:

$$\mu(\tilde{S}_d, \tilde{V}_z)^* = \max\left\{\sum_{\gamma=1}^{p} w_\gamma \cdot \mu_u(\tilde{S}_d, \tilde{V}_z),\, z = \overline{1,\, f}\right\}.$$

The selected pair is taken as the best solution.

Scenario 3.2. The task of decisions making shall be reduced to the multi-objective task of choosing the best solution, taking into account the relative importance of the criteria that characterize workplaces.

Decision-making methods and algorithms are developed for each of the proposed scenarios and implemented in an experiment to address the decision support on the recruitment of medical professionals.

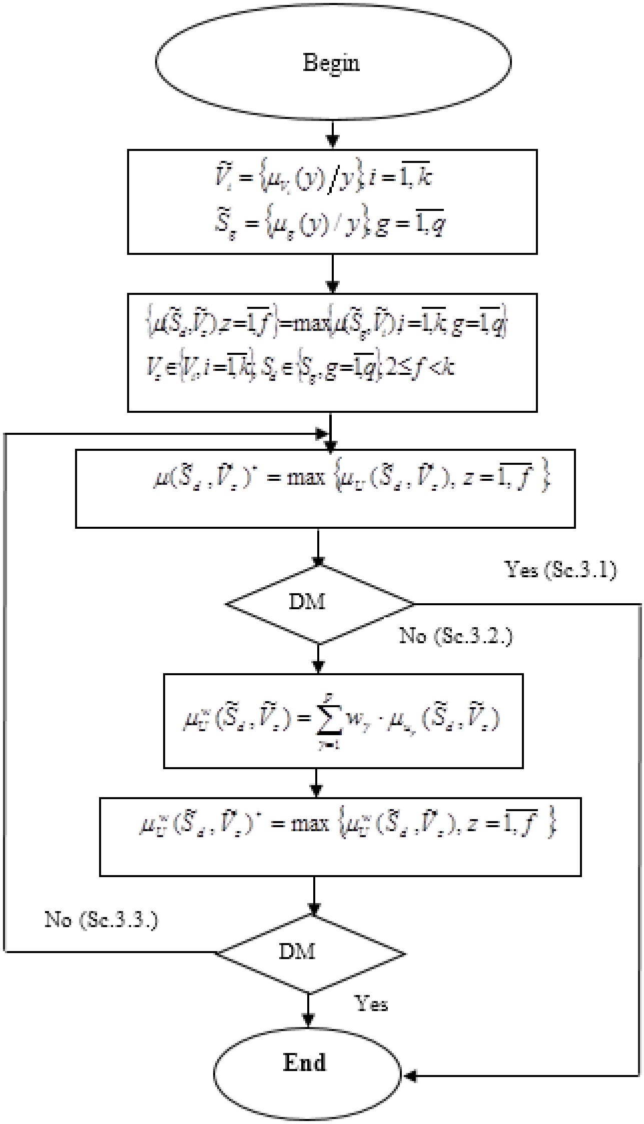

Figure 8. Block diagram of the decision-making process for scenario 3

Conclusion

1. Scientific and theoretical aspects of HRM were analyzed, the tasks of decision support on the hierarchical levels of HRM were determined; the need for using a fuzzy mathematical apparatus for their modeling was proved.
2. A method of forecasting demographic indicators based on the model of fuzzy time series were proposed for decision support in the formation of personnel and socio-economic policy of the state; an intellectual system of demographic forecasting was developed.
3. A labor market model for decision support in the formation of long-term employment policy of the country was proposed; and a methodology for multi-scenario forecasting and scheduling of labor market using the hierarchy analysis method (HAM) was developed.
4. A method for estimating the efficiency of the labor market and its subsystems based on fuzzy relational model was developed; taking into account the hierarchical structure of the criteria.
5. A method for estimating family incomes to identify low-income families in the poverty reduction system was developed.
6. Specific features of the HRM tasks of the organization predetermining its weak structure and multi-criterion nature of the decision-making tasks were proposed; a conceptual and generalized model of these problems was proposed.
7. Methods of decision-making on HRM tasks in organizations based on additive and multiplicative aggregation were proposed; appropriate algorithms and tools were developed for decision support for the management of scientific and technical personnel.
8. A methodology for multi-criteria ranking based on HAM and modification of TOPSIS was proposed; an appropriate algorithm was developed and implemented in phases for decision support in the personnel recruitment.
9. Methods were proposed for initial information processing for decision support in HRM tasks; a method for mathematical

description of criteria, a method for determining the relative importance of criteria, and a method for identifying contradictions in expert assessments were proposed.

10. Multi-scenario decision methods showing employers' requirements for a "job portrait" in the recruitment of IT professionals were developed.
11. A methodology for personnel recruitment in virtual organizations based on HAM and multiplicative aggregation was proposed and implemented.
12. Methods for decision-making in a distributed environment for the evaluation of the performance of the personal in virtual organizations were proposed.
13. Given the multivariance of supply and demand of medical personnel, scenarios were proposed, according to which the methods and algorithms for decision support in the management of medical personnel were developed basing on the degree of fuzzy proximity of the fuzzy situation of supply and demand.
14. A multi-scenario methodology for managing supply and demand was implemented on the example of recruitment of medical personnel applying for certain vacancies.
15. The tools and packages of applied programs for the management of the human resources of a country by the hierarchy levels were developed and implemented.

The main content of the dissertation is represented in 40 scientific publications:

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Z.Q.Cəbrayılova, M.İ.Manaflı; – Bakı: İnformasiya Texnologiyaları Nəşriyyatı, – 2009. – 199 s.
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The personal role of applicant in works published with co-authors:

[1], [7], [34] – a methodology of population forecasting was developed based on fuzzy time sequence model, the methodology was compared; results were calculated, an algorithm of relevant software product was developed; functional scheme of intellectual demographic forecasting system was proposed;

[2] – application opportunities of decision-making methods in solving fragmentary-distributed environment in solving HRIM problems were studied;

[3] – a methodology for planning the desired state of labor market was proposed, an experiment was performed to forecast and plan labor market in Azerbaijan;

[4], [33] – a methodology to support the targeting of assistance to low-income families was developed, the implementation stages were described; functional scheme of system was proposed;

[5] – a methodology for assessing the effectiveness of labor market was proposed;

[6], [12], [13], [15], [17], [20], [30] – scalar optimization methods to solve HRIM problem in the organization were proposed; fuzzy relation model, additive and multiplicative aggregation methods, decision algorithms based on HAM and modified TOPSIS were developed; experiments were conducted, and the results were compared;

[8] – scientific-analytical analysis of survey results on demand and supply monitoring for IT specialists was performed;

[9], [26] – multi-scenario decision-making methods were developed; related algorithm to solve recruitment problem of IT specialists was proposed;

[10], [11] – methods for input data processing to solve HRIM problems in organization were developed, experiments were performed;

[18], [19], [35] – scenarios based on multi-scenario approach for intellectual management of supply and demand in IT labor market were developed, a system of criteria was formed, and an experiment was performed;

[24], [27], [28] – situation related to demand and supply management in medical staff segment was analyzed; decision-making methods and algorithms on possible scenarios in terms of consistency of supply and demand were developed, experiments were conducted;

[25] – big data integration into HRIM tasks solution and their application problems were analyzed, perspective research trends were proposed;

[29] – production rules of disbalance for the intellectual management of supply and demand in the IT labor market in accordance with linguistic values were developed;

[31] [32] – decision-making methods in fragmentary distributed environment were proposed to address HRIM issues in VO; employee selection and performance evaluation algorithms were developed;

[36] – results of research conducted on human resource formation of e-medicine and intellectual management of medical professionals were presented.

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