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DEVELOPMENT OF A MULTI-SCENARIO APPROACH TO INTELLIGENT MANAGEMENT OF HUMAN RESOURCES IN THE FIELD OF MEDICINE

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Досліджено проблеми управління людськими ресурсами в медичній сфері. Показано особливості попиту і пропозиції на ринку праці медспеціалістів, що ідентифікують завдання управління як слабоструктуровану. Запропонована нечітка ситуаційна модель попиту і пропозиції на медспеціалістів, постановка задачі інтелектуального управління їх узгодженням. Розроблено методику прийняття рішень для найму медспеціалістів, що базується на нечіткому розпізнавання образів

Ключові слова: медспеціалісти, модель попиту, модель пропозиції, нечіткі ситуації, нечітка схожість

Исследованы проблемы управления человеческими ресурсами в медицинской сфере. Показаны особенности спроса и предложения на рынке труда медспециалистов, идентифицирующие задачу управления ими как слабоструктурируемую. Предложены нечеткая ситуационная модель спроса и предложения на медспециалистов, постановка задачи интеллектуального управления их согласованием. Разработана методика принятия решений для найма медспециалистов, базирующаяся на нечетком распознавании образов

Ключевые слова: медспециалисты, модель спроса, модель предложения, нечеткие ситуации, нечеткое сходство

1. Introduction

The health care system activities determining the population health index are directly dependent on the human resources in this field. Levels of medical personnel supply and continuous occupational training directly influence the health care quality indices [1, 2].

The issues of planning personnel potentials development, study of the problems associated with matching demand for medical specialists and their supply are quite pressing all over the world. Not by chance, these issues are among the major concerns of the World Health Organization (WHO) and their solution is recommended for all countries [3, 4].

Currently, traditional approaches to the study and management of demand for medical specialists and their supply do not ensure the expected effect. Experience shows that the few existing approaches to the management of human resources in the field of medicine are mainly based on statistical and analytical data. However the imperfect methods of collecting statistical data in this area, their incompleteness and temporal discrepancy impede an adequate primary description of the medical labor market state [2]. As for the qualitative (competency) aspects of supply and demand, their evaluation is only possible based just on the expert estimations.

Demand for medical specialists in many countries including Azerbaijan is much greater than their supply [5, 6]. At the same time, a number of problems of matching demand for medical specialists and their supply reduce to removal of their quantitative and structural imbalance. Another, more significant part of the problems requires consideration of qualitative aspects brought about by the dynamism and diversification of requirements of concrete health-care service consumers (employers).

In literature, there is no sufficient attention paid to the study of demand for medical specialists and their supply through the prism of the employers' needs as well as to working out efficient methods of the employment process management. Also, there is no a uniform and generally accepted method of analysis and evaluation of human resources in the health care [2, 4]. All this determines necessity of working out alternative approaches to the supply and demand management in the medical labor market.

2. Literature review and problem statement

For many years, an adverse dynamics of human resources is observed in the medical field likewise a tendency of personnel outflow and their often shortages [4, 5]. The WHO report points out that the world community will miss 12.9 million medical specialists in 2035 and that the current shortage makes 7.2 million [4].

As predicted for certain states of the USA, shortage of doctors will be as high as 85,000 in 2020. In accordance with [5, 6], shortage of physicians varies within 55,000 to 200,000. These data are valid under the condition that American medical schools will succeed in enlarging number of their graduates by 3,000 annually.

It is expected that the demand for doctors will exceed their supply by 46,000 to 90,000 in 2025 [7].

The State Statistics Service of Russian Federation registered 501 doctors for 100,000 people in 2009, 418 in 2011 and it turned out that in all 367,222 doctors were actually working while the normative figure was 520,028 [5]. At the end of 2013, the number of medical specialists 7,261 less than in 2012, and if the figures for the first 6 months of 2013 and 2014 are compared, the number of doctors in Russia has decreased by 14,703 [8]. There was one doctor for 593 people in Turkey in 2011; the corresponding figure was 408 for the United States, 262 for Germany, 203 for Ukraine, 290 for Azerbaijan [9]. In 2011–2015, the number of doctors decreased from 37 to 35 per 10,000 people in Azerbaijan, from 54 to 41 in Belarus, from 50 to 49 in Russia, from 49 to 44 in Ukraine and so on [10].

The total number of doctors includes all specialists having higher medical education and employed in various medical institutions. Examples of medical institutions include patient care and sanitary institutions, social security institutions, scientific research institutions, public health establishments, organizations preparing medical specialists, etc. [5, 10].

Shortage is observed in mid-level medical specialists (doctor's assistants, midwives, nurses). For example, there was shortage of 35,000 nurses in the United Kingdom and more than 100,000 in Finland in 2008 [5]. The number of Russian paramedical personnel has decreased by 20,723 during 2011–2012 [9]. The doctor/nurse ratio in the United Kingdom is 1:1.9 [4], 1:2.1 in Russia [5, 9, 10] and 1:1.7 in Azerbaijan [10] compared to normative ratio 1:3.

The situation at the medical labor market confirms once again the fact of excess of today's demand for medical personnel over their supply. This, in turn, actualizes the need of development of more efficient approaches to the management of medical specialist supply and demand.

The present-day labor market of paramedical workers is characterized by complexity of acquisition of reliable information on its condition, contradictory stream of the data forming demand and supply, difficulty of measuring statistical information on the demand for paramedical workers and their supply and an ambiguous definition of the system of indices characterizing the latter, their quantitative and qualitative nature.

At present, an intensive growth of medical knowledge volume and an accelerating implementation of medical discoveries into practice are observed. On the other hand, duration of manpower development and their narrow specialization grow [11, 12]. Widespread introduction of high-tech equipment and the dynamics of emergence of new therapies should also be noted. The abovementioned makes new demands to paramedical specialists, such as high adaptability to changes and innovations, flexibility and willingness to develop new skills, ability to switch to innovative kinds of activity.

The acquisition of these qualities is only possible by continuous updating professional knowledge and skills both in the formal and informal education.

Above features identify the problem of supply and demand management in the paramedical labor market as a semi-structured and hard to formalize problem [13, 14]. This determines a variety of possible fuzzy states of paramedical supply and demand and a multivariate nature of their matching [15]. Solution of the problem of comparison and evaluation of these states and making decisions on the choice of the policy of their matching can be effective when using intelligent methods and technologies.

Therefore it seems appropriate to develop a scientific and methodological approach to management of supply and demand for medical personnel. Of special interest here is development of a decision-making procedure for recruitment of medical specialists based on fuzzy pattern recognition and methods of fuzzy similarity of situations.

3 The aim and tasks of the study

This work objective is to develop a decision-making procedure for recruitment of medical specialists based on fuzzy pattern recognition and the methods of fuzzy similarity of situations. The results obtained can be used as a basis for scientific and methodological approach to the intelligent management of demand and supply of medical staff at the level of medical institutions [16, 17].

To achieve the objective, the following tasks were set:

– modeling processes of interaction between supply and demand in the medical labor market;

– statement of the decision-making problem on matching supply and demand for medical specialists;

– elaboration of scenarios of demand and offer management for the problem of medical specialist employment and working out corresponding decision-making methods;

– implementation of the proposed procedure of managing medical specialist supply and demand.

4. Modeling the processes of interaction between supply and demand in the medical labor market

Success of performing professional duties by medical specialists depends on their intellectual capabilities, the degree of possession of specific professional and personal competence, readiness to adequately apply them at a particular workplace, willingness and ability to develop and regularly update their knowledge and experience in the professional field in accordance with the functional requirements to the latter. On the other hand, in the conditions of market economy and growing importance of employees as the main strategic resource of any organization, necessity of taking into account (by employers) the preferences (claims, interests, motivations) of medical specialists directly influencing their further professional growth and creativity in performing professional duties acquires a high actuality in the human resource management. In this context, approach to the labor market as to the intellectual environment in which knowledge and skills act as the product is promising [17, 18].

4. 1. Problem statement

Specify demand at the medical specialist labor market by the set:

$V=\{V_1,V_2,...,V_k\}$ or $V=\{V_i\}$, $i=\overline{1,k}$, expressed by the number of vacancies;

$L=\{l_1,l_2,...,l_n\}$ or $L=\{l_j\}$, $j=\overline{1,n}$ is the set of personal characteristics (features) to be owned by the candidate for a certain post (position, working place);

$C=\{c_1,c_2,...,c_m\}$ or $C=\{c_f\}$, $f=\overline{1,m}$ is the open set of competences to be owned by the candidate for the medical vacancy;

$U=\{u_1,u_2,...,u_p\}$ or $U=\{u_\gamma\}$, $\gamma=\overline{1,p}$ is the set of conditions proposed to the candidates for the vacant medical work places.

The demand model $V=(L,C,U)$ can be described by three matrices:

$$V_L=\|l_{ij}\|_{kn},\ V_C=\|c_{if}\|_{km},\ V_U=\|u_{iz}\|_{kp},$$

where each $i=\overline{1,k}$ line V_i characterizes a separate vacancy at the medical labor market;

columns (l_n, c_m, u_p) represent constantly expanding database of personal characteristics and competencies;

elements l_{kn}, c_{km} is the level of possession of separate indicators necessary to obtain a vacancy;

u_{kp} are values of indicators characterizing conditions offered to the candidate for a particular vacancy.

The degree of satisfaction of vacancy V_i to indicators l_{ij}, c_{if} and u_{kp} is defined as fuzzy sets with membership functions

$$\mu_{l_{ij}}(V_i): V\times L\to[0,1],\ \mu_{c_{if}}(V_i): V\times C\to[0,1],$$

$$\mu_{u_{i\gamma}}(V_i): V\times U\to[0,1], \quad (1)$$

expressing the level of possession of individual competencies required to fill a vacancy specified by employers, fuzzy measures of intensity of the indicators characterizing conditions of employment.

Specify the supply at the medical labor market by a set $S=\{S_1,S_2,...,S_q\}$ or $S=\{S_g\}, g=\overline{1,q}$ of medical specialists seeking for a job and applying for one or other vacancy.

– $L=\{l_j\}, j=\overline{1,n}$ is the set of personal features that characterize medical specialists;

– $C=\{c_f\}, f=\overline{1,m}$ is the set of real competences possessed by each concrete candidate for the vacancy;

– $U=\{u_\gamma\}, \gamma=\overline{1,p}$ is the set of preferences of the medical specialist expressed in the form of his requirements to the medical vacancy.

The model of supply $S=(L,C,U)$ is also described by three matrices

$$S_L=\|l_{gj}\|_{qn},\ S_C=\|c_{gf}\|_{qm},\ S_U=\|u_{g\gamma}\|_{qp},$$

where each line (S_g) ($g=\overline{1,q}$) characterizes an individual candidate for the vacancies at the medical labor market; columns (l_n, c_m, u_p) reflect the constantly expanding base of personal features and competences; elements l_{qn}, c_{qm} are the level of possession by individual features necessary to get the vacancy; u_{qp} are the values of indicators describing the medical specialist's requirements to the vacant workplace.

The degree of possession by a concrete medical specialist S_g $g=\overline{1,q}$ of a separate competence is determined by the membership function

$$\mu_{l_{gj}}(S_g): S\times L\to[0,1],\ \mu_{c_{gf}}(S_g): S\times C\to[0,1],$$

$$\mu_{u_{g\gamma}}(S_g): S\times U\to[0,1]. \quad (2)$$

In fact, 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:

$$\tilde{V}_i=\{<\mu_{l_{gj}}(V_i)>,<\mu_{c_{gr}}(V_i)>,<\mu_{u_{gz}}(V_i)>\}=\{\mu_{V_i}(y)/y\}, \quad (3)$$

$$\tilde{S}_g=\{<\mu_{l_{gj}}(S_g)>,<\mu_{c_{gr}}(S_g)>,<\mu_{u_{gz}}(S_g)>\}=\{\mu_{S_g}(y)/y\}. \quad (4)$$

There set

$$\tilde{V}_i=\{\mu_{V_i}(y)/y\}\ \ i=\overline{1,k}$$

is the description of fuzzy reference situations and the set

$$\tilde{S}_g=\{\mu_{S_g}(y)/y\}\ \ g=\overline{1,q}$$

is the description of fuzzy real situations.

The essence of intelligent management of supply and demand in the medical labor market consists in solution of the decision-making problem on the adequacy of the reference and real-life situations using fuzzy pattern recognition.

4. 2. The problem solution

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.

The procedure of pattern recognition involves the following steps:

– determine real situations (search images of medical specialists) in accordance with the values of indicators characterizing each candidate for the vacancy;

– determine reference situations (search demand images) according to the values of indicators characterizing the employer's requirements to the candidate for the vacancy;

– calculate the degree of similarity of the reference situation to each real situation in accordance with the chosen measure of assessment of similarity between two fuzzy situations;

– define the real situation with the greatest degree of similarity to the reference one. In other words, a decision is made on hiring one medical specialist (supply) for the declared vacancy (demand) who matches most closely the employer requirements.

Various measures for determining the degree of similarity between two fuzzy situations including one-step or multi-step estimation procedures are discussed in [14, 19, 20]. In the present work, the degree of fuzzy inclusion of situation $\tilde{S}_g$ into situation $\tilde{V}_i$ and the degree of fuzzy equality $\tilde{V}_i$ and $\tilde{S}_g$ were used as the measures of estimation of the degree of proximity of fuzzy real and reference situations.

1. According to [19], the degree of fuzzy inclusion of situation $\tilde{S}_g$ into situation $\tilde{V}_i$ is defined as follows:

$$\theta(\tilde{S}_g,\tilde{V}_i)=\&\,\theta(\mu_{S_g}(y),\mu_{V_i}(y))=$$
$$=\underset{y\in Y}{\&}(\max(1-\mu_{S_g}(y),\mu_{V_i}(y)))=$$
$$=\min(\max(1-\mu_{S_g}(y),\mu_{V_i}(y))). \quad (5)$$

The situation $\tilde{S}_g$ is considered fuzzily included into situation $\tilde{V}_i$ ($\tilde{S}_g \tilde{\subseteq} \tilde{V}_i$) if the degree of inclusion of $\tilde{S}_g$ into $\tilde{V}_i$ is not less than some threshold of inclusion $\psi\in[0,6;\ 1]$ defined by the management conditions, i. e. $\theta(\tilde{S}_g,\tilde{V}_i)\ge\psi$.

In other words, $\tilde{S}_g \subseteq \tilde{V}_i$, if the values of supply indicators $\tilde{S}_g$ are fuzzily included into the values of demand indicators $\tilde{V}_i$.

The process of pattern recognition reduces to estimation of the degree of similarity of the reference situation (demand) to each of the alternative real situations (supply). To make a decision on selection of the most suitable candidate for recruitment from a set of real-life situations that satisfy the inclusion threshold, one is selected which provides maximum to expression:

$$\max\left[\min(\max(1-\mu_{S_g}(y),\mu_{V_i}(y)))\right],\ g=\overline{1,q},\ i=\overline{1,k}.$$

2. The degree of fuzzy equality (equivalence) as a measure for determination of proximity of any two fuzzy situations is based on the following reasoning. Let the threshold of equality of two situations (e. g., $\psi\in[0,7;1]$) is set and there are situations which mutually include each other, i. e.

$$\tilde{S}_g \subseteq \tilde{V}_i \text{ and } \tilde{V}_i \subseteq \tilde{S}_g,\ \ g=\overline{1,q},\ \ i=\overline{1,k}, g\neq k,$$

($\subseteq$ is the sign of a fuzzy inclusion), then situations $\tilde{S}_g$ and $\tilde{V}_i$ are considered approximately equal. Such similarity of situations called fuzzy equality is determined from the expression:

$$\mu(\tilde{S}_g,\tilde{V}_i)=\vee(\tilde{S}_g,\tilde{V}_i)\,\&\vee(\tilde{V}_i,\tilde{S}_g)=$$
$$=\&\,\mu(\mu_{S_g}(y),\mu_{V_i}(y)=$$
$$=\min_{y\in Y}\begin{bmatrix}\min(\max(1-\mu_{S_g}(y),\mu_{V_i}(y)),\\ \max(1-\mu_{V_i}(y),\mu_{S_g}(y)))\end{bmatrix}. \quad (6)$$

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

5. Scenarios and methods of matching supply of and demand for medical specialists

Authors of work [15] defined possible scenarios of matching demand and supply of medical specialists. In that way, 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 (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) of which one must be chosen as corresponding to the most suitable candidate.

In this case, various decision-making methods can be offered to the employer in his capacity of an expert (decision maker):

Scenario 2. 1. The decision making task reduces 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.

In this case, the degree of proximity between the reference $\tilde{V}_i$ and real $\tilde{S}_g$. situations is calculated according to (5) or (6). Further on, using some specified threshold of equality (e. g., $\psi\in[0,7;1]$), situations are determined which mutually include each other or are fuzzily equal. A real situation having the highest degree of proximity to the reference one is selected as the sought situation.

Scenario 2. 2. The decision-making task reduces to a multicriterion choice of the best possible solution (alternative) taking into account the relative importance of the criteria characterizing medical specialists [21].

In this case, the decision-making task is realized in the following stages:

Stage 1. By analogy with scenario 2. 1, situations are determined which mutually include each other or are fuzzily equal. Following this operation, "narrowing" of the set of real situations is possible. E. g., the real situations with their degree of similarity to the reference one less than the threshold specified by the employer are eliminated.

Stage 2. Determine coefficients of relative importance:

w_L, w_C, w_U (based on fuzzy relations $L\times C\times U$);

w_{l1} ,w_{l2},..., w_{ln} (based on fuzzy relations of indicators $l_1\times l_2\times\ldots\times l_n$);

w_{c1} ,w_{s2},..., w_{cm} (based on fuzzy relations of indicators $c_1\times c_2\times\ldots\times c_m$);

w_{u1}, w_{u2},..., w_{up} (based on fuzzy relations of indicators $u_1\times u_2\times\ldots\times u_p$);

2. 1. To determine the coefficients of relative importance of indicators, the 9-point Saaty scale is used (Table 1) [22].

Table 1

9-point Saaty scale

Mark	Linguistic assessment of pairwise comparison
1	equivalence
3	moderate dominance
5	strong dominance
7	very strong dominance
9	the highest (extreme) dominance
2, 4, 6, 8	intermediate values between two neighbor scale values

If there are n indicators, then based on n–1 relations reflecting the pairwise comparison of these indicators, a matrix of pairwise comparisons based on such matrix characteristics as diagonality ($K_{ii}=1,\ i=\overline{1,n}$), symmetry $K_{ij}=K_{ji}^{-1}$ and transitivity $K_{ig}\cdot K_{gj}=K_{ij}$ can be composed.

2. 3. After the elements of the matrix of pairwise comparisons based on the method proposed in [22] are determined, relative importance of the indicators are calculated. According to this method, the sum of elements in each line is divided by the total sum of the matrix elements. The first element of the resulting vector corresponds to the coefficient of importance of the first indicator, the second element corresponds to the coefficient of importance of the second indicator and so on.

2. 4. When using the pairwise comparisons, it is necessary to identify contradiction of the expert assessments and to that end, the maximum matrix eigenvalue λ_{max}, consistency index (CI), consistency ratio (CR) are determined.

According to the method of obtaining a rough estimate of consistency, the following steps are performed to solve this problem [23]:

– multiply the matrix of comparisons to the right by the obtained estimate of the solution vector (i. e. by the coefficients of relative importance of the indicators) to determine a new vector;

– divide the first component of this vector by the first component of the solution vector estimate, divide the second component of the new vector by the second component of solution estimate, etc. to determine another vector;

– divide the sum of the components of the obtained vector by the number of components to calculate the value of λ_{max};

– consistency index (CI) is determined based on the formula below:

$$CI = (\lambda_{max} - n) / (n - 1); \quad (7)$$

– the ratio of the consistency index corresponding to random consistencies (RC) determines the value of consistency:

$$CR = CI / RC. \quad (8)$$

According to [22], RC=0.58 for matrices n=3, RC=0.90 for the matrices n=4, RC=1.12 for matrices n=5, RC=1.24 for matrices n=6 and so on.

If the value $CR \le 0{,}1$, then the value of consistency is considered acceptable, otherwise, to eliminate contradictions in the assessments, experts are invited to revise their preferences.

Stage 3. Based on the aggregation of degrees of possession of individual indicators,

$$\mu_{l_{gj}}\left(S_g\right),\ j = \overline{1,n},\ \mu_{c_{gf}}\left(S_g\right),\ f = \overline{1,m},\ \mu_{u_{g\gamma}}(S_g),\ \gamma = \overline{1,p}$$

for concrete medical specialists $S_g, g = \overline{1,q}$, the degrees of similarity of fuzzy real situations to the reference situation are determined at further stages [21, 24]:

3. 1. Based on the "convolution" $\mu_{l_{gj}}\left(S_g\right),\ j = \overline{1,n}$, the degree of similarity between real and reference situations is determined by personal characteristics (L):

$$\phi_L\left(\tilde{S}_g\right) = \sum_{j=1}^{n} w_j \mu_{l_j}\left(S_g\right). \quad (9)$$

3. 2. Based on the "convolution" $\mu_{c_{gf}}\left(S_g\right), f = \overline{1,m}$, the degree of similarity between real and reference situations in the context of competences (C) is determined:

$$\phi_C(\tilde{S}_g) = \sum_{f=1}^{m} w_f \cdot \mu_{c_f}(S_g). \quad (10)$$

3. 3. Based on the "convolution" $\mu_{u_{g\gamma}}(S_g), \gamma = \overline{1,p}$, the degree of similarity between real and reference situations is determined through the prism of requirements to vacancy U:

$$\phi_U(\tilde{S}_g) = \sum_{\gamma=1}^{p} w_\gamma \mu_{u_\gamma}(S_g). \quad (11)$$

3. 4. Based on the results obtained and the coefficients of relative importance L, C and U (w_L, w_C, w_U) the degree of similarity between real and reference situations is determined:

$$\phi_{\tilde{V}_i}\left(\tilde{S}_g\right) = \omega_L \cdot \phi_L(\tilde{S}_g) + \omega_C \cdot \phi_C(\tilde{S}_g) + \omega_U \cdot \phi_U(\tilde{S}_g). \quad (12)$$

3. 5. Select the fuzzy real situation with a maximum value:

$$\phi_{\tilde{V}_i}\left(\tilde{S}^*\right) = \max\left\{\phi_{\tilde{V}_i}\left(\tilde{S}_g\right), g = \overline{1,n}\right\}. \quad (13)$$

The selected fuzzy real situation matches the search image of the applicant having the highest degree of similarity to the reference vacancy image and is accepted as the best solution.

6. Implementation of the procedure of managing supply of and demand for medical specialists based on calculation of the degree of similarity of fuzzy situations

Suppose there are two vacancies:

V_1 – pediatrician for the city private clinic;

V_2 – pediatrician for the regional clinic for which 4 medical specialists $S = \{S_1, S_2, S_3, S_4\}$ apply.

Consider the stages of realization of the problem of selecting candidates for above two vacancies from the four candidates using the degree of their fuzzy equality to determine proximity of the two situations.

Stage 1: Determination of the reference situational model of vacancy reducing to selection of indicators characterizing employer's requirements to the vacancy. To form a system of indicators characterizing the vacancy, information on hiring medical specialists obtained at recruiting websites was used [24–28].

The system of indicators for vacancy V_1:

Personal qualities (L):

– sociability (l_1);

– responsibility (l_2);

– self-perfection, willingness to develop oneself (l_3).

Competences, knowledge and skills (C):

– the level of professional knowledge in pediatrics according to the diploma of higher education (c_1);

– knowledge in pediatrics at a professional level (c_2);

– free PC operation (c_3);

– skill of grammatically correct presentation in writing (c_4).

Requirements and conditions of the vacancy (U):

– minimum 3 years of practical work (u_1);

– certificate of postgraduate courses (u_2);

– free possession of Azerbaijan and Russian languages (u_3).

The system of indicators for the vacancy V_2:

Personal qualities (L):

– responsibility, attentiveness (l_1);

– adaptability to environment (l_2).

Competences, knowledge and skills (C):

– level of professional knowledge in pediatrics according to the diploma of higher education (c_1);

– knowledge in pediatrics at a professional level (c_2).

Requirements and conditions of the vacancy (U):

– work in a region or a village (u_1):

– work at a tensioned schedule (u_2);

– free knowledge of Azerbaijan language (u_3).

Stage 2: To determine the degree of candidate possession of separate indicators characterizing the vacancy it is necessary to formalize indicators, i.e. it is necessary to operate with linguistic variables and their values that express verbal rating scales for measuring [29–31]. The scales of estimation reflect in an ascending order the intensity of indicator manifestation (excellent, good, normal, fair, poor). Table 2 shows the 5-level values of the linguistic variable "sociability" and their corresponding ranges of variation of fuzzy degrees of possession of this indicator in the range [0; 1].

Table 2

Fuzzification of "sociability"indicator

Graduations of "sociability"indicator	Linguistic estimate	The range of variation of fuzzy degrees in interval [0; 1]
very sociable	excellent	[0.95–1]
sociable	good	[0.8–0.94]
weakly sociable	normal	[0.5–0.79]
nonsocial	fair	[026–0.49]
reserved	bad	[0–0.25]

Stage 3. Linguistic estimates of the candidates for the vacancy are given in Table 3.

Table 3

Linguistic estimates of the candidates for the vacancy

candidates for vacancy V_1 / indicators characterizing vacancy V_1	S_1	S_2	S_3	S_4
Personal qualities (L):				
sociability (l_1)	excellent	good	good	normal
responsibility (l_2)	good	good	good	good
self-perfection, willingness to develop oneself (l_3)	good	good	normal	good
Competences, knowledge and skills (C):				
level of professional knowledge in pediatrics according to the diploma of higher education (c_1)	excellent	excellent	good	excellent
knowledge of pediatrics at a professional level (c_2)	good	good	normal	good
free operation of PC (c_3)	excellent	excellent	good	good
skill of grammatically correct presentation in writing (c_4).	good	excellent	good	normal
Requirements and conditions of the vacancy (U):				
minimum 3 years of practical work (u_1)	good	good	excellent	excellent
certificate of postgraduate courses (u_2)	good	good	excellent	excellent
free possession of Azerbaijan and Russian languages (u_3)	excellent	excellent	good	good

The degrees of the candidates' possession of the indicators characterizing vacancy V_1, are shown in Table 4.

Table 4

The degrees of the candidates' possession of the indicators characterizing vacancy V_1

candidates / indicators characterizing vacancy V_1	S_1	S_2	S_3	S_4
Personal quaities (L):				
sociability (l_1)	0.97	0.88	0.82	0.65
responsibility (l_2)	0.89	0.85	0.89	0.82
self-perfection, willingness to develop oneself (l_3)	0.87	0.8	0.70	0.9
Competences, knowledge and skills (C):				
level of professional knowledge in pediatrics in accordance with the diploma of higher education (c_1)	0.98	0.95	0.82	0.97
knowledge of pediatrics at a professional level (c_2)	0.9	0.84	0.75	0.88
free PC operation (c_3)	0.95	0.97	0.80	0.82
skill of grammatically correct presentation in writing (c_4)	0.82	0.95	0.9	0.70
Requirements and conditions of the vacancy (U):				
minimum 3 years of practical work (u_1)	0.90	0.94	0.97	0.96
certificate of postgraduate courses (u_2)	0.82	0.82	0.97	0.95
free possession of Azerbaijan and Russian languages (u_3)	0.95	0.95	0.8	0.88

Based on Table 4, fuzzy real situations, i. e. fuzzy images of the candidates for the position V_1, are formed:

$$\tilde{S}_1=\begin{Bmatrix}0{,}97/l_1;0{,}89/l_2;0{,}87/l_3;0{,}98/c_1;0{,}9/c_2;\\ 0{,}95/c_3;0{,}82/c_4;0{,}9/u_1;0{,}82/u_2;0{,}95/u_3\end{Bmatrix},$$

$$\tilde{S}_2=\begin{Bmatrix}0{,}88/l_1;0{,}85/l_2;0{,}8/l_3;0{,}95/c_1;0{,}84/c_2;\\ 0{,}97/c_3;0{,}95/c_4;0{,}94/u_1;0{,}82/u_2;0{,}95/u_3\end{Bmatrix},$$

$$\tilde{S}_3=\begin{Bmatrix}0{,}82/l_1;0{,}89/l_2;0{,}70/l_3;0{,}82/c_1;0{,}75/c_2;\\ 0{,}8/c_3;0{,}95/c_4;0{,}97/u_1;0{,}97/u_2;0{,}8/u_3\end{Bmatrix},$$

$$\tilde{S}_4=\begin{Bmatrix}0{,}65/l_1;0{,}82/l_2;0{,}9/l_3;0{,}97/c_1;0{,}88/c_2;\\ 0{,}82/c_3;0{,}7/c_4;0{,}96/u_1;0{,}95/u_2;0{,}88/u_3\end{Bmatrix}.$$

Reference fuzzy image of vacancy V_1 is described as follows:

$$\tilde{V}_1=\begin{Bmatrix}1/l_1;1/l_2;1/l_3;1/c_1;1/c_2;\\ 1/c_3;1/c_4;1/u_1;1/u_2;1/u_3\end{Bmatrix}.$$

Stage 4: Using formula (6), the degrees of fuzzy equality of reference $\tilde{V}_1$ and real-life $\tilde{S}_1$, $\tilde{S}_2$, $\tilde{S}_3$, $\tilde{S}_4$ situations are determined:

– by personal indications (L):

$$\mu_L(\tilde{V}_1,\tilde{S}_1)=0{,}87;\quad \mu_L(\tilde{V}_1,\tilde{S}_2)=0{,}8;$$

$$\mu_L(\tilde{V}_1,\tilde{S}_3)=0{,}70;\quad \mu_L(\tilde{V}_1,\tilde{S}_4)=0{,}65;$$

– by competences (C):

$\mu_C(\tilde{V}_1,\tilde{S}_1)=0,82;\ \ \mu_C(\tilde{V}_1,\tilde{S}_2)=0,84;$

$\mu_C(\tilde{V}_1,\tilde{S}_3)=0,75;\ \ \mu_C(\tilde{V}_1,\tilde{S}_4)=0,7;$

– by the requirements to the vacancy (U):

$\mu_U(\tilde{V}_1,\tilde{S}_1)=0,82;\ \ \mu_U(\tilde{V}_1,\tilde{S}_2)=0,82;$

$\mu_U(\tilde{V}_1,\tilde{S}_3)=0,8;\ \ \mu_U(\tilde{V}_1,\tilde{S}_4)=0,88.$

Based on the obtained results, the degree of fuzzy equality $\mu(\tilde{V}_1,\tilde{S}_g),\ \ g=\overline{1,4}$ of the reference vacancy image V_1 and search images of real situations $\tilde{S}_1,\ \tilde{S}_2,\ \tilde{S}_3,\ \tilde{S}_4$ is determined:

$$\mu(\tilde{V}_1,\tilde{S}_1)=\mu_L(\tilde{V}_1,\tilde{S}_1)\,\&\,\mu_C(\tilde{V}_1,\tilde{S}_1)\,\&\,\mu_U(\tilde{V}_1,\tilde{S}_1)= \\ =0,87\,\&\,0,82\,\&\,0,82=0,82,$$

$$\mu(\tilde{V}_1,\tilde{S}_2)=\mu_L(\tilde{V}_1,\tilde{S}_2)\,\&\,\mu_C(\tilde{V}_1,\tilde{S}_2)\,\&\,\mu_U(\tilde{V}_1,\tilde{S}_2)= \\ =0,8\,\&\,0,4\,\&\,0,82=0,8,$$

$$\mu(\tilde{V}_1,\tilde{S}_3)=\mu_L(\tilde{V}_1,\tilde{S}_3)\,\&\,\mu_C(\tilde{V}_1,\tilde{S}_3)\,\&\,\mu_U(\tilde{V}_1,\tilde{S}_3)= \\ =0,7\,\&\,0,75\,\&\,0,8=0,7,$$

$$\mu(\tilde{V}_1,\tilde{S}_4)=\mu_L(\tilde{V}_1,\tilde{S}_4)\,\&\,\mu_C(\tilde{V}_1,\tilde{S}_4)\,\&\,\mu_U(\tilde{V}_1,\tilde{S}_4)= \\ =0,65\,\&\,0,7\,\&\,0,88=0,65.$$

Stage 5. The results of the linguistic estimation of the candidates $S=\{S_1, S_2, S_3, S_4\}$ for the vacancy V_2 are shown in Table 5.

Table 5

Results of linguistic estimation of the candidates for the vacancy V_2

indicators characterizing vacancy V_2 \ candidates for vacancy V_2	S_1	S_2	S_3	S_4
Personal qualities (L):				
responsibility, attentiveness (l_1)	good	good	good	good
adaptability to environment (l_2)	normal	good	normal	good
Competences, knowledge and skills (C):				
level of professional knowledge in pediatrics in accordance with the diploma of higher education (c_1)	excel-lent	excel-lent	good	excel-lent
knowledge of pediatrics at a professional level (c_2)	excel-lent	excel-lent	good	good
Requirements and conditions of the vacancy (U):				
work in a region (or village) (u_1)	good	good	normal	good
work by a tensioned schedule (u_2)	normal	good	normal	good
free possession of the Azerbaijan language (u_3)	excel-lent	excel-lent	good	good

The degrees at which the candidates possess indicators characterizing the vacancy V_2 are given in Table 6.

Table 6

Degrees at which the candidates possess indicators characterizing the vacancy V_2

indicators characterizing vacancy V_2 \ candidates for vacancy V_2	S_1	S_2	S_3	S_4
Personal qualities (L)				
responsibility, attentiveness (l_1)	0.85	0.9	0.88	0.86
adaptability to environment (l_2)	0.6	0.92	0.75	0.94
Competences, knowledge and skills (C)				
level of professional knowledge in pediatrics in accordance with the diploma of higher education (c_1)	0.97	0.96	0.85	0.96
knowledge of pediatrics at a professional level (c_2)	0.98	0.96	0.82	0.85
Requirements and conditions of the vacancy (U)				
work in a region (or a village) (u_1)	0.8	0.9	0.75	0.88
work at a tensioned schedule (u_2)	0.65	0.9	0.77	0.85
free possession of Azerbaijan language (u_3)	0.96	0.96	0.85	0.9

Thus, fuzzy real situations corresponding to the fuzzy search images of candidates for the vacancy V_2 are formed:

$$\tilde{S}_1=\begin{Bmatrix}0,85/l_1;0,6/l_2;\ 0,97/c_1;0,98/c_2;\\ 0,8/u_1;0,65/u_2;0,96/u_3\end{Bmatrix},$$

$$\tilde{S}_2=\begin{Bmatrix}0,9/l_1;0,92/l_2;\ 0,96/c_1;0,96/c_2;\\ 0,9/u_1;0,9/u_2;0,96/u_3\end{Bmatrix},$$

$$\tilde{S}_3=\begin{Bmatrix}0,88/l_1;0,75/l_2;\ 0,85/c_1;0,82/c_2;\\ 0,75/u_1;0,77/u_2;0,85/u_3\end{Bmatrix},$$

$$\tilde{S}_4=\begin{Bmatrix}0,86/l_1;0,94/l_2;0,96/c_1;0,85/c_2;\\ 0,88/u_1;0,85/u_2;0,9/u_3\end{Bmatrix}.$$

Reference fuzzy image of vacancy V_2 can be described as follows:

$$\tilde{V}_2=\{1/l_1;1/l_2;\ 1/c_1;1/c_2;\ 1/u_1;1/u_2;1/u_3\}.$$

Based on the procedure set forth above, the degree of fuzzy equality $\mu(\tilde{V}_2,\tilde{S}_g),\ \ g=\overline{1,4}$: is determined:

$$\mu(\tilde{V}_2,\tilde{S}_1)=\mu_L(\tilde{V}_2,\tilde{S}_1)\,\&\,\mu_C(\tilde{V}_2,\tilde{S}_1)\,\&\,\mu_U(\tilde{V}_2,\tilde{S}_1)= \\ =0,6\,\&\,0,97\,\&\,0,65=0,6,$$

$$\mu(\tilde{V}_2,\tilde{S}_2)=\mu_L(\tilde{V}_2,\tilde{S}_2)\,\&\,\mu_C(\tilde{V}_2,\tilde{S}_2)\,\&\,\mu_U(\tilde{V}_2,\tilde{S}_2)= \\ =0,9\,\&\,0,96\,\&\,0,9=0,9,$$

$$\mu(\tilde{V}_2,\tilde{S}_3)=\mu_L(\tilde{V}_2,\tilde{S}_3)\,\&\,\mu_C(\tilde{V}_2,\tilde{S}_3)\,\&\,\mu_U(\tilde{V}_2,\tilde{S}_3)= \\ =0,75\,\&\,0,82\,\&\,0,75=0,75,$$

$$\mu(\tilde{V}_2,\tilde{S}_4)=\mu_L(\tilde{V}_2,\tilde{S}_4)\,\&\,\mu_C(\tilde{V}_2,\tilde{S}_4)\,\&\,\mu_U(\tilde{V}_2,\tilde{S}_4)= \\ =0,86\,\&\,0,85\,\&\,0,88=0,85.$$

The obtained results are given in Table 7.

Table 7

Degrees of fuzzy equality $\mu(\tilde{V}_1,\tilde{S}_g), g=\overline{1,4}$ and $\mu(\tilde{V}_2,\tilde{S}_g), g=\overline{1,4}$

Candidates	$\mu(\tilde{V}_1,\tilde{S}_g), g=\overline{1,q}$	$\mu(\tilde{V}_2,\tilde{S}_g), g=\overline{1,q}$
S_1	**0.82**	0.6
S_2	0.8	**0.9**
S_3	0.7	0.75
S_4	0.65	0.85

Stage 6. The obtained results correspond to scenario 2. 1, i. e. by the degree of fuzzy equality of the reference situation $\tilde{V}_1$ and the real situations $\tilde{S}_1$, $\tilde{S}_2$, $\tilde{S}_3$, the real situation $\tilde{S}_1$ is the most close with its value $\mu(\tilde{V}_1,\tilde{S}_1)=0{,}82$.

The reference situation $\tilde{V}_1$ and the fuzzy real situation $\tilde{S}_4$ are fussily unequal since the admissibility threshold is not satisfied, i. e.

$$\mu(\tilde{V}_1,\tilde{S}_4)=0{,}65<0{,}7.$$

For the second vacancy, by the degree of fuzzy equality of the reference situation $\tilde{V}_2$ and the real situations $\tilde{S}_2$, $\tilde{S}_3$, $\tilde{S}_4$, the real situation $\tilde{S}_2$ is the nearest situation with its value

$$\mu(\tilde{V}_2,\tilde{S}_2)=0{,}9.$$

Reference situation $\tilde{V}_2$ and fuzzy real situation $\tilde{S}_1$ are fuzzily unequal because

$$\mu(\tilde{V}_2,\tilde{S}_1)=0{,}6<0{,}7.$$

Stage 7. Assume that in accordance with the employer preferences in selection of a suitable candidate he is most interested not in an equal consideration of all indicators but just individual ones. In this case, the problem of decision-making is reduced to scenario 2. 2 which also takes into account the degree of relative importance of indicators. As the real situations $\tilde{S}_4$ and $\tilde{S}_1$ for the vacancies $\tilde{V}_1$ and $\tilde{V}_2$ fall out of consideration, then three alternative candidates will take part in each of further estimations.

7. 1. Determine the relative importance of the indicators characterizing vacancy V_1.

Based on the estimate of the relative importance of the employer's preferences by various criteria (Table 1), a pairwise comparison matrix is built. In this case, "the criterion C has the highest superiority over L and a moderate superiority over U" (Table 8).

Table 8

Matrix of pairwise comparison of L·C·U

	L	C	U
L	1	0.11	0.33
C	**9**	1	**3**
U	3	0.33	1

Divide the sum of the values of the line elements by the sum of the values of the matrix elements to calculate factors of the relative importance: w(L)=0.077; w(C)=0.693; w(U)=0.23. Next, determine consistency of expert estimations:

$$\begin{pmatrix} 1 & 0{,}11 & 0{,}33 \\ 9 & 1 & 3 \\ 3 & 0{,}33 & 1 \end{pmatrix} \times \begin{pmatrix} 0{,}077 \\ 0{,}693 \\ 0{,}23 \end{pmatrix} =$$

$$= \begin{pmatrix} 1\times 0{,}077+0{,}11\times 0{,}693+0{,}33\times 0{,}23 \\ 9\times 0{,}077+1\times 0{,}693+3\times 0{,}23 \\ 3\times 0{,}077+0{,}33\times 0{,}693+1\times 0{,}23 \end{pmatrix} = \begin{pmatrix} 0{,}23 \\ 2{,}08 \\ 0{,}7 \end{pmatrix},$$

$$\lambda_{max}=(0{,}23:0{,}077+2{,}08:0{,}693+0{,}7:0{,}23)/3=$$
$$=(2{,}99+3{,}01+3{,}04)/3=9{,}04/3=3{,}01.$$

Based on formula (7):

CI=(3.01–3)/(3–1)=0.01/2=0.0125.

Based on formula (8):

CR=0.0125/0.58=0.02.

Thus, the value of consistency $CR<0{,}1$, means that there is consistency of expert estimates.

7. 2. Similarly, based on the expert preferences, coefficients of the relative importance of the indicator values are determined, and the consistency of expert estimates is checked. In this case:

– "indicator l_2 has a very strong advantage over indicators l_1 and l_3";

– "indicators c_1 and c_2 have a strong advantage over indicators c_3 and c_4";

– "indicator u_1 has a strong advantage over indicators u_2 and u_3".

7. 3. The results are shown in Table 9.

Table 9

Coefficients of relative importance of the indicators and the degree of possessing the indicators characterizing vacancy V_1

Criteria	Coefficient of relative importance of L, C, U	Indicators	Coefficient of relative importance of indicator values	$\tilde{S}_1$	$\tilde{S}_2$	$\tilde{S}_3$
L	0.077	l_1	0.07	0.97	0.88	0.82
		l_2	0.465	0.89	0.85	0.89
		l_3	0.465	0.87	0.8	0.70
C	0.693	c_1	0.4166	0.98	0.95	0.82
		c_2	0.4166	0.9	0.84	0.75
		c_3	0.0834	0.95	0.97	0.80
		c_4	0.0834	0.82	0.95	0.9
U	0.23	u_1	0.714	0.90	0.94	0.97
		u_2	0.143	0.82	0.82	0.97
		u_3	0.143	0.95	0.95	0.8

Stage 8. Based on the results obtained and formulas (9)–(11), the degrees of closeness of real images to the reference image $\tilde{V}_1$ for L, C, U are determined:

$$\phi_L(\tilde{S}_i)=\sum_{j=1}^{3}\phi_{l_j}(S_i)\cdot w_{l_j},\ \phi_C(\tilde{S}_i)=\sum_{f=1}^{4}\phi_{c_f}(S_i)\cdot w_{c_f},$$

$$\phi_U(\tilde{S}_i)=\sum_{\gamma=1}^{3}\phi_{u_\gamma}(S_i)\cdot w_{u_\gamma}.$$

The results are shown in Table 10.

Table 10

Degree of closeness of the real images to the reference image for L, C, U

Reference situation		Coefficient of relative importance	$\tilde{S}_1$	$\tilde{S}_2$	$\tilde{S}_3$
$\tilde{V}_1$	L	0.077	0.88	0.83	0.8
	C	0.693	0.93	0.91	0.8
	U	0.23	0.9	0.92	0.95

Stage 9. Based on formula (11), the degree of closeness of the real situations to the reference situation is determined. The results are shown in Table 11.

Table 11

Closeness of the real situations $\tilde{S}_1$, $\tilde{S}_2$, $\tilde{S}_3$ to the reference situation $\tilde{V}_1$

Degree of closeness	$\tilde{S}_1$ $\mu(V_1,S_1)\to[0,1]$	$\tilde{S}_2$ $\mu(V_1,S_2)\to[0,1]$	$\tilde{S}_3$ $\mu(V_1,S_3)\to[0,1]$
$\mu(\tilde{V}_1,\tilde{S}_g)$	0.919	0.906	0.834

As it follows from Table 11, the real search image of candidate S_1 has a maximum degree of closeness to the reference search image of vacancy V_1 and is the best solution.

Likewise the best solution among the candidates for the vacancy V_2 is determined.

7. Discussion of the results obtained in the study of managing matching supply of and demand for medical specialists

As is well known, human resources of organizations are the main factor of their competitiveness. Therefore, the issues of support of the decision making processes involved in the management of human resources and their intellectual potential at various management levels gain strategic importance.

The necessity of backing-up decision-making in management of medicine is determined by a number of specific factors including dynamics of medical knowledge, intensification of specialization, uneven geographical and territorial distribution of medical specialists and therefore the variation in the claimed requirements. The following should also be noted: high cost of training of qualified medical personnel, growth in value of the latter with accumulation of experience and professionalism, increased demand for medical specialists at a general trend towards decrease in their supply. In these circumstances, the present-day employers must constantly adapt their decisions to the ever-changing management situations. Moreover, what is observed today at all levels is a significant increase in the portion of decisions that need to be made in vague and non-standard situations. To cope with this challenge, a more flexible fuzzy model is required to support management decision-making processes, and the present work suggests the fuzzy pattern recognition in the capacity of such model.

It should be noted that the theory of pattern recognition has a wide range of applications in solving problems of medical diagnostics. In the referenced literature, the problem of fuzzy pattern recognition is considered mainly in the context of a support for physicians in their diagnostic and treatment decision-making and it is reducing to classification of images based on location of the particular disease class as close to the reference image as possible [32–34].

A series of works [35–37] are devoted to intellectual management of human resources. However, these studies do not take into account the diversity of situations and subjectivity of assessments occurred in a real situation. The effectiveness of application of the fuzzy pattern recognition in the tasks of human resource management is defined by ensuring greater closeness to the simulated object condition and making decisions with their accuracy correlated with the initial situations.

The procedure proposed in this paper makes it possible to reduce subjectivity in the evaluation of diverse information about the current state of supply and demand for medical specialists and enables decision-making adequate to the formed situation. This procedure is invariant for the management of human resources in various segments of economy subject to its adaptation to the features of the segment under study.

This study is a further evolvement of the intelligent management methods of supply and demand in the labor market of IT professionals. The problem can be developed in the direction of expansion of the set of possible scenarios of matching supply and demand and creation of appropriate decision-making methods. The proposed procedure for the selection of medical staff can also be developed in the direction of creation of a decision-support system based on social networks using the approaches proposed in papers [38, 39].

8. Conclusions

1. From the standpoint of the individual labor market participants (medical specialists and employers) and their behavioral strategies, the models of supply and demand interaction were developed. Their characteristic feature is consideration of the employers' requirements representing description of fuzzy reference situations and preferences of medical specialists describing fuzzy real situations.

2. Formulation of the decision-making problem in matching supply of and demand for medical specialists is given. The problem is reducible to the fuzzy pattern recognition. Pattern recognition is based on the fuzzy situational analysis and determination of the degree of similarity of fuzzy situations. As the degree of measures of evaluation of the degree of proximity between two fuzzy situations, the degrees of their fuzzy inclusion and fuzzy equality were used.

3. The developed multi-scenario approach to the intelligent management of human resources in the field of medicine takes into account the multivariate nature of coordination of supply and demand in the medical labor market in real situations. Possible scenarios of supply and demand relationships were offered and appropriate decision support methods were developed for each of them in the problems of employment of medical specialists.

4. The phased implementation of the procedure for multi-scenario supply and demand management in the process of selection and recruitment of medical specialists has shown that the decisions made by each scenario are the best among the better from the standpoint of satisfying both requirements of the employer and claims of the applicants.

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