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Approaches to harmonize supply and demand in the labor market of IT professionals

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Abstract: The objective of this work is to study of theoretical and applied aspects of supply and demand for IT specialists in the labor market taking into account the global employment trends (at macro level), and regional employment trends. The paper suggests approaches to the formation and interaction of supply and demand in the labor market for IT professionals and management of their quantitative mismatch at the macro level, intelligent IT-market control schemes, structural imbalances assessment, the degree of imbalance between supply and demand, imbalance inconsistency algorithm, etc. New technologies and tools are developed in the market of various specialists with a view to control supply and demand. However, techniques used to formally describe the supply and demand in the labor market and to consider dynamic requirements of employers, imply the development of innovative approaches and methods with regard to specificities of this economic sector. Fast and sustainable economic growth and competitiveness, implies the need for IT staff training and development; this staff having skills relevant to the labor market needs requires the development of new, more flexible approaches and methods for matching supply and demand for IT professionals. This determined significance of research can be helpful for all stakeholders in taking well-founded decisions on managing the imbalance between supply and demand in the IT professionals labor market. The authors made an attempt of modeling the interaction of supply and demand processes in the labor market for IT professionals, and assessed the degree of their balance at the macro level.

Key words: IT, Labor market, Supply, Demand, Qualitative imbalance, Quantitative imbalance, Situational management, Fuzzy reference, Real conditions, Fuzzy, Fuzzy mismatch scale

1. Introduction

Everyone recognizes the special role of information and communication technologies (ICT) in the development of the world and national economies, the acceleration of the processes of transiting to a knowledge-based economy, increasing the efficiency, competitiveness and innovation potential of economic branches and enterprises. The use of ICT in various domains of human activity, the expansion of the population's access to various information resources and transformation of information into a global resource have caused a sharp increase in demand for IT specialists on the labor market, which far exceeds their supply in many countries. Thus, the deficit of IT specialists is recorded in practically every country of the European Union today(E-Skills for Jobs in Europe; Skill mismatch Identifying priorities for future research; European Vacancy Monitor). Experts forecast that by 2020 the number of vacancies in the IT field will increase to at least 750,000 or one million at most compared to 274, 000 in 2013. This will happen against the background of a decline in the number of IT, engineering or natural science students in the EU.

The rising demand for IT specialists and their insufficient supply is recorded in such developed countries as the USA and Canada (Wennergren, 2007). CIS member states, including Azerbaijan, which are actively integrating in the global information space, have also encountered the problem of the discrepancy of supply and demand of IT specialists(Shortage of IT specialists; Mammadova et al. 2009;IT personnel 2010). In conformity with the Development Concept "Azerbaijan 2020: Look into the Future", the volume of the ICT sector should grow four times (*Development Concept "Azerbaijan 2020: Look into the Future",* Shortage of IT specialists), which is a serious challenge for the system of IT specialist training.

The role of IT in the social and economic development of the county and the need for state participation in the regulation of IT specialists' labor market by means of adjusting the education system to the needs of the latter are universally acknowledged. However, the elaboration of adequate technologies and methods of support for managerial decisions on the coordination of supply and demand for IT specialists which takes into account the specifics of this sector and its main actors, i.e. IT specialists (supply) and employers (demand), remain open.

2. Literature review

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At present the labor market and the market of education have different mechanisms and time frames of functioning. The education system develops on the basis of long-term policies and strategies, whereas the IT industry must respond to fast changing market demands and technological innovation in order to remain competitive on the global, national and local markets (Bartlett, 2012; CATTANEO et al., 2009; *Forecast and Anticipation for Skills Supply and Demand in ETF Partner Countries*, 2013). There is a time gap (sometimes quite a broad one) between decision-making as regards investments in the training of specialists with certain competencies and the release of these specialists with professional skills onto the labor market.

Such measures as standardization of competency profiles, elaboration of professional and educational standards in the sphere of IT in which employers are involved; expansion of the quota of admissions to IT faculties has contributed to some extent to approximation of the markets of labor and education. However, these two fields continue to function independently (*Department for Employment and Learning. Research Study on High-Level Skill Needs in NI ICT Sector*, 2009, *Research Study on High-Level Skill Needs in NI ICT Sector*, 2009, *Thinking Ahead on E-Skills for the ICT Industry in Europe*, 2007; Doucek et al., 2012; Mammadova and Mammadzadeh, 2012; Paterson and Roodt, 2008; Salzman et al., 2013). The discordance of SD on the market of ITS can be explained by: 1) quantitative imbalance as a result of lack or oversupply of ITS, including in terms of certain IT jobs and specializations; 2) qualitative imbalance which is accounted for by a) structural misalignment of occupational training of ITS as a result of obsolescence of some IT skills and emergence of other, principally new IT jobs and specializations and the education system's delayed response to some of the labor market demands; b) the discrepancy between the knowledge and skills as well as practical experience of IT specialists formed by educational institutions and those required by the labor market; 3) various combinations of the indicated kinds of imbalance(Van der Heijden et al., 2010; Mammadova et al., 2014a; Vincent and Tremblay-Côté, 2011). The decisions taken to coordinate supply and demand for IT specialists will be different for each type of imbalance or a combination of them.

Why are traditional methodologies for addressing the quantitative and qualitative deficiencies on the labor market which consist in filling vacancies and decreasing the unemployment level not effective today? The reason is that the constantly changing economic situation and the renewal and shortening of the cycle of change of technologies and knowledge and global IT penetration contribute to changing expectations as regards IT jobs and the emergence of new IT jobs. This leads to either oversupply or deficit of certain jobs and skills, which leads to an increase in structural unemployment or employment outside one's specialization. The growing flexibility of demand on the one hand and the inefficiency of IT education as regards the provision of competencies required by the labor market contribute to the imbalance between supplies (IT specialists) and demand (IT vacancies). The discrepancy between supply and demand for skills leads to structural imbalance and brings about a decrease in the competitiveness of enterprises and the country as a whole.

Modern approaches to eliminating quantitative and qualitative incongruities on the labor market presuppose the employers' setting competence requirements for IT jobs. The competencies that are seen through the prism of formal qualifications of IT experts embody their professional skills, knowledge and individual experiences as well as personality traits and predetermine their employment, career growth etc. Competencies are also an important factor and mechanism in the elaboration and coordination of policies in the field of work, education and economic development (European Commission.; Employment and Social Development Canada; Wilson 2010).

The contemporary market of IT specialists is characterized by complexity of obtaining verifiable information about its state, the contradictory nature of the flow of data as regards the supply and demand of IT specialists and the difficulty of measuring them, the lack of complete statistics on this matter as well as the difficulty of analyzing it; the ambiguity of features which characterize supply and demand, their quantitative and qualitative characteristics and the fast rate of IT development. These features of the analyzed segment of the market lead to growing vagueness of 'source' information and lower the efficiency of decisions as regards human resource management in the IT sector. The above mentioned characteristics which make the task of managing supply and demand on the IT market a complex one (Mammadova, 1997; Mammadova and Jabrayilova, 2015), make it necessary to expand the scope of traditional mathematical methods of modelling of the labor market by turning to new approaches and techniques based on intelligent control of human resources.

The approaches and models of assessing supply and demand on the labor market suggested in individual works (Azarnova et al., 2013; Fasih, 2008; Gainanov and Galliamov, 2006; Pouliakas, 2014; Sigova, 2011; Vasilyev et al., 2007) do not allow one to manage its separate segments efficiently, since the labor market is not an aggregate of the labor markets in specific branches of the economy. Specific features of every segment of the national economy, the conditions, factors and rates of development of the economic branches account for their various contributions to the general state of the labor market and necessitate the research of individual segments. Insufficient substantiation and the contradiction of methodological and conceptual approaches to researching the labor market of IT specialists call for a comprehensive examination of this sector of the economy.

3. Research results

3.1. The aim and tasks of the research

The aim of this study is the development of models and methods of assessment of the imbalance between supply and demand at the micro- and macrolevels on the basis of a conceptual approach to intelligent control of the IT specialists' labor market which is proposed by the authors. The following tasks are aimed at achieving this objective:

- to define the notion of intelligent control of supply and demand on the labor market of IT specialists;
- to identify the components of the intelligence system of management of the IT specialists' labor market;
- to elaborate a transaction scheme of the system of intelligent control of supply and demand on the IT specialists' labor market;
- to develop a method for assessing the qualitative imbalance of supply and demand;
- to develop a method for assessing the quantitative imbalance of supply and demand.

The study describes the authors' approach to fulfilling the above tasks.

3.2. Intelligent control of supply and demand on the labor market of IT specialists

At present demand plays the main role in the supply-and-demand interconnection in many economic sectors, including IT. It is quite robust and presents certain challenges to supply. However, the system of occupational training lags behind technological innovation and continues to produce specialists whose knowledge and skills are not adequate to the current and future needs of the labor market. Employers complain about deficient results of the education system's functioning without taking any real effort to improve the training of future IT personnel.

This suggests the necessity of new strategic approaches to IT specialist training including closer contacts with employers who are now obliged to carry out the training, retraining and further training of IT experts on their own (Feiler et al., 2013). At the same time, employers need to participate more actively in the processes of developing the professional knowledge and skills, the advancement in training and further training of IT specialists (Mammadova et al., 2014a).

We regard the elaboration of an intelligent system of managing the coordination of ITS as one of the ways of reducing the imbalance between them and quick adjustment of IT experts' supply to the fast-changing needs of the economy.

By intelligent control of SD of the market of ITS the authors mean managerial decision-making on the coordination (balancing) of the SD of ITS which comes down to: 1) generating alternative policy options (measures, strategies, tactics) in accordance with a specific task and the supply and demand at a given moment (period) of time; 2) making a managerial decision in keeping with the aim and terms of the task set as well as with the needs and preferences of the main actors of the labor market (employers and IT specialists) on the one hand and ensuring minimal difference between supply and demand on the other.

The aim of intelligent control of SD of ITS (human resources in the IT) consists in making well-grounded managerial decisions on staffing various branches of the national economy with qualified specialists.

3.3. Conceptual approach to investigating the labor market of IT specialists

The shift of emphasis onto the human factor and its intellectual component determines the need to review the content of the main components of the labor market. According to the concept advanced by the authors (Mammadova and Mamedzadeh 2015), the labor market is seen as an intellectual space (environment or system) in which its subjects who represent demand (employers) and supply (IT experts) operate. The latter's competences which embody their personal intellectual potentials expressed by knowledge; skills and aptitudes as well as "soft" skills and idiosyncrasies are seen as the product of the IT segment of the labor market.

The processes and mechanisms of the management of SD of the market of ITS and managerial decision-making for their coordination are directly affected by the subjects of the labor market, who are represented by: 1) mediators (offline and online recruiting agencies); 2) the state which exerts influence on the number and structure of IT jobs by legal regulation and economic measures (tax policies, investment policies, creation of new IT jobs etc.); 3) providers of education who ensure the supply of ITS to the labor market and control the quantity of the latter by constantly training them.

Interpreting the content of the main subjects of the labor market of ITS in keeping with the realities of knowledge-based economy allows one to identify the following basic structural components of intelligent control of the coordination of the labor market:

1) demand for IT experts from the perspective of the needs of enterprises (employers) which is reflected in IT job requirements;
2) supply, i.e. applicants for IT jobs who offer their intellectual potentials formed by means of continuous education services;
3) mechanisms of identifying the correlation between supply and demand on the IT labor market which embody the degree of coordination (imbalance) of demand for IT specialists and their supply (models and methods of assessing the balance of supply and demand);
4) mechanisms of managing the coordination of SD on the market of ITS (methods of support of managerial decision-making which come down to

elaboration of policies in the sphere of labor and employment and adjustment of IT education and training to labor market needs).

The specified set of components provides an opportunity to reveal sets of states of SD of ITS, the modeling of the trends of the latter's changes through time and elaboration of control with regard to their quantitative and qualitative balancing (Mammadova et al., 2014b, 2015a).

3.4. Generalized model of the intelligent system of managing the labor market of ITS

Based on the principles of the systems approach and the general concept of intelligent control of S and D on the labor market of ITS, the generalized model of the intelligent system of management of the labor market of ITS can be described in the following way:

$$I_s = \{Z, V, S, K, M, R, T\}. \quad (1)$$

where Z is the goal of the intelligent system of managerial decision-making for coordination of S and D on the relevant labor market, V is the set of vacancies, the search cases of which are represented by employers' (decision-makers') expectations of the qualifications, professional and personality characteristics (competencies) of applicants for specific IT jobs; S is a set of IT specialists applying for the jobs the search cases (professional images) of which are represented by a set of competences that each applicant has; K is a set of core competences that characterize an IT specialist applying for a relevant job; M is a set of models and methods of measuring the S and D on the labor market of ITS and assessing their coordination; R is a set of managerial decisions aimed at minimizing the imbalance of SD of the market of ITS; T is a set of time horizons or times of observation during which the SD of the market of ITS are assessed.

The process of managing the SD of the market of ITS according to goal Z, comes down to implementation of a correlation between set V of vacancies which contain the employer's expectations and set of IT specialists S each of whom has certain competencies. The vectors of S and D are input, control parameters of the intelligent system, E are external and internal factors affecting S and D of ITS. We regard set of managerial decisions R which are formed by the intelligent system of management of the ITS labor market as output parameters of the intelligent system.

The conceptual model of the functioning of the intelligent system of management can be formally expressed by rules of conversion of input parameters into output ones and described in a simplified way as $F : V \cdot S \cdot Z \cdot E \to R$, where F is the rule of conversion in the system of management of S and D of ITS by which any mathematical formulas, logical operations, set-theoretical correlations etc are understood.

The formalization of supply and demand relations at the IT labor market allows to model processes of management of S and D by means of interaction of such components as:

- the model of an ITS' competences (Mammadova and Mammadzadeh, 2012);
- the model of demand for ITS which defines the requirements for specific IT jobs (Mammadova et al., 2014, 2015);
- the model of supply determining the search-image (professional portrait) of specific ITS and their preferences;
- the model of identification of the state of supply and demand and coordination of their objectives (Mammadova et al., 2014; Mammadova, Jabrayilova, & Mammadzada, 2014b, 2014c);
- the model of managing the conditions on the market of IT experts and adjusting the system of IT education to needs of the labor market (Mammadova, Jabrayilova, & Mammadzada, 2015; Vincent &Tremblay-Côté, 2011).

3.5. Modeling of the processes of interaction and evaluation of the imbalance of SD on the market of ITS

In the examination of the processes of coordination of S and D it is also necessary to clearly identify the level at which the imbalance is assessed. Thus, the task of modelling the processes of interaction of S and D on the labor market of ITS and their management can be examined at the micro- and macrolevels. At the macrolevel the task of identifying the states of S and D is examined from the viewpoints of individual subjects of the labor market (IT experts and employers) and their behavioral strategies. Enterprise is the smallest unit at this level. It is at the level of enterprise that the structure and volume of demand for ITS as well as expectations of their professional competencies and personal intelligences are specified. Given this, the establishment of the degree of coordination between S and D at the micro level boils down to elaboration of mechanisms of effective selection and recruitment of ITS.

At the macro level the modeling of the processes of interaction of S and D of ITS comes down to balancing the relevant supply and demand within the bounds of a territorial or geographical entity (at the levels of economic branches, regions, country as a whole etc). Being subsystems of a single labor market, the micro- and macrolevels are inextricably linked in a relation of interpenetration.

In formal terms, the problem of identification of supply and demand conditions can be defined by three components $D = < V, S, R >$, where

- V is the set of vacancies;
- S is the set of IT specialists;
- R is the set of rules defining the relationship between the elements of sets V and S, i.e., rules

helping to compare the descriptions of actual conditions of IT specialists with all reference conditions of the demand side.

The recognition and evaluation of supply and demand take the form of the mapping $F : D \to Z$, where Z is the solution of the problem D set with the intelligent system as a particular target condition meeting the purpose of recognition and evaluation in a particular situation.

At the micro level these are rules that allow correlating the descriptions of the real states of IT specialists and all the reference states of demand (qualification criteria set by the employer for job applicants) and reveal the difference between them.

At the macro level these are rules that allow establishing the composite supply and demand of IT specialists in various IT jobs and specializations as well as the degree of their balance which reflects the conditions of the market and IT specialists.

3.6. Managing the discrepancy between supply and demand of IT specialists at the micro level

Let $M_V = \{V, K, G, Q, U^p\}$ be a model of demand for IT professionals, defining requirements for the competence of the applicant to a particular workplace. The latter one is a system of employers' preference regarding specific job applicant, which are expressed by a set of desired competencies of the candidate, and it forms a search image of IT professional. Here V is a set of vacancies expressed with demands of employers for IT professionals, i.e. applicants for vacancies, $K = (L, C)$ is a set of core competencies characterizing IT professional, which is formed by L - a set of personal competencies needed to work in the IT sector, and by C - a set of professional competence, reflecting the necessary ability of functionality to be engaged in a particular position. G is a system of employer's preferences regarding owning individual indicators, $Q : V \cdot K \cdot U^p \to G$ is a decisive rule (assessment model) to display the system of employer's preferences to the set of competencies, U^p is a set of conditions, proposed to the candidates for IT profile position.

Proposal model $M_S = \{S, K, W, Q^*, U^s\}$ reflects the actual values of competencies and preferences of each individual IT professionals, identifying real search image (professional portrait) of IT professionals. Here S is a set of IT professionals seeking a job and applying for a particular job, $K = (L, C)$ is a set of personal characteristics and professional competencies of a specific IT specialist, i.e. a potential applicant for a specific job, W is a system of preferences of IT professionals, $Q^* : S \cdot K \cdot U^s \to W$ displays the system of preferences of IT specialist to a set of competencies, U^s is the requirements of IT professionals for IT-profile work place.

During the interaction of a set of standard states of demand for IT professionals and the set of real states, that define their supply, many unique semi structured (fuzzy) situations are formed.

The goal of the management problem of supply and demand in the labor market of IT professionals is the identification (recognition) of real search images of IT professionals and etalon query search images of the exact same pair, the conformity (proximity) degree of the elements of which has the greatest value from both the preference position (reference requirements) of the employer, and from the standpoint of the applicant claims.

3.6.1. Solution of the management problem of supply and demand in the labor market of IT professionals

Let the market demand of IT professionals be a set $V = \{V_1, V_2, ..., V_k\}$ or $V = \{V_i\}, i = \overline{1,k}$ specified, expressed in number of vacancies; $L = \{l_1, l_2, ..., l_n\}$ or $L = \{l_i\}, j = \overline{1,n}$ is a set of personal characteristics (features), which each candidate must have at a specific position (position, job), $C = \{c_1, c_2, ..., c_m\}$ or $C = \{c_f\}, f = \overline{1,m}$ is an open set of competencies, which each candidate must have for the position of IT profile, $U^p = \{u_1, u_2, ..., u_p\}$ or $U^p = \{u_\gamma\}, \gamma = \overline{1,p}$ is a set of conditions, which are proposed for the candidates for the vacant IT profile jobs.

Demand model $V = (L, C)$ can be described by three matrices $V_L = \|l_{ij}\|_{kn}$, $V_C = \|c_{ir}\|_{km}$, and $V_U = \|u_{iz}\|_{kp}$, where each row (V_i) describes a separate position in the IT labor market; the columns (l_n, c_m) display constantly expanding base of personality characteristics and competencies; the elements l_{kn}, c_{km} are the level of possessing separate indicators needed to fill a vacancy at time *t*; u_{kp} is the values of parameters characterizing the conditions offered for the applicant to fill a particular vacancy. Here, a weight of competencies may also be taken into account, i.e. $\lambda = \{\lambda_1, \ldots, \lambda_n\}$ a set of weights of personal competences $L = \{l_i\}, j = \overline{1,n}$;

$\omega = \{\omega_i, \dots, \omega_m\}$ is a set of weights of professional competencies.

Satisfaction rate of V_i vacancy for the indicators l_{ij} and c_{ir} is defined as fuzzy sets with membership functions

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

,

which express the rate of owning individual competencies required by the given employers to fill a vacancy.

At the same time, the conditions offered to applicants are described by matrix $V_U = \|u_{iz}\|_{kp}$, where the membership functions $\mu_{u_{iz}}(V_i): V \times U \to [0,1]$ are fuzzy measures of indicator intensity, characterizing the conditions of employment.

Let the market supply of IT professionals be expressed by

$S = \{S_1, S_2, \dots, S_q\}$ - a set of IT professionals and job seekers applying for a particular job. $L = \{l_i\}, j = \overline{1,n}$ is a set of personal characteristics, characterizing IT professionals; $C = \{c_f\}, f = \overline{1,m}$ is a set of real competences possessed by each individual candidate to fill the vacancy;

$U = \{u_\gamma\}, \gamma = \overline{1,p}$ is a set of preferences IT professional, expressed as the requirements to IT profile job. $S = (l, c)$ - the demand model is also described by three matrices

$S_L = \|l_{ij}\|_{kn}$, $S_C = \|c_{ir}\|_{km}$ and $S_U = \|u_{iz}\|_{qp}$, where each row (S_q) describes a separate candidate for the job in the IT labor market;

the columns (l_n, c_m) reflect the constantly expanding base of personality characteristics and competencies;

the elements l_{qn}, c_{qm} are the rate of possessing different characteristics needed to fill a vacancy; u_{qp} is the indicator value, describing the requirements of IT- specialist to the vacancies.

The rate of possession of specific IT professional competence S_l is determined by a separate membership function

$$\mu_{l_{ij}}(S_i): S \times L \to [0,1], \ \mu_{c_{ir}}(S_i): S \times C \to [0,1]$$

Requirements of IT professionals for a vacancy are expressed by matrix $S_U = \|u_{iz}\|_{cp}$, and $\mu_{u_{cz}}(S_i): S \times U \to [0,1]$ is a fuzzy measure of requirements for intensity of IT professionals.

Actually, there are two sets of fuzzy conditions, describing the state of supply $\tilde{V}_k$ and demand $\tilde{S}_q$ in the labor market of IT professionals:

$$\tilde{S}_q = \{< \mu_{l_{ij}}(S_q) >, < \mu_{c_{ir}}(S_q) >, < \mu_{u_{iz}}(S_q) >\} = \{\mu_{S_q}(y)/y\}$$

$$\tilde{V}_k = \{< l_{ij}(V_k) >, < \mu_{c_{ir}}(V_k) >, < \mu_{u_{iz}}(V_k) >\} = \{\mu_{V_k}(y)/y\}$$

Here $\tilde{S}_q = \{\mu_{S_q}(y)/y\}$ is a description of the set of fuzzy etalon situations, and $\tilde{V}_k = \{\mu_{V_k}(y)/y\}$ is the set of description of fuzzy real situations.

To determine the state of the management object, i.e. supply and demand, it is reasonable to reduce the identification problem of corresponding supply and demand to the problem of fuzzy pattern recognition and evaluation criteria, and to the rate of their possession. Search and decision making, in this case, are reduced to the comparison of each fuzzy search image of IT professionals with each etalon fuzzy search image of employers' queries, and to the identification of pairs with the highest rate of proximity. In this formulation, decision-making in accordance with supply and demand on the basis of situational management using the measures of proximity definition of two fuzzy situations, where proximity measures such as the rate of fuzzy shift of $\tilde{S}_q$ fuzzy situation into $\tilde{V}_k$ fuzzy situation, the rate of fuzzy equality $\tilde{V}_k$ and $\tilde{S}_q$, the rate of fuzzy commonness $\tilde{V}_k$ and $\tilde{S}_q$, and etc. may be used(Melikhov, Bernshtein, & Korovin, 1990; Zadeh, 1975).

3.7. Managing the imbalance between S and D on the market of labor of ITS at the macro level

In conformity with the adopted concept of the functioning of the labor market of ITS, we propose a transaction scheme of intelligent control of the latter (Fig. 1).

We have taken into consideration the fact that the education services market is one of the main sources of workforce inflow onto the labor market and an infrastructure element of its regulation, including various occupational-skills groups(Ilyin et al., 2001). This provides an opportunity to elaborate a model of interaction between the system of vacancies (demand), the IT workforce (supply), the institutions influencing the processes and

mechanisms of managing the S and D of ITS and to establish the composite D (S) at the level of any territorial and geographical entity and country as a whole. Another vital function is performed by the market of educational services. By systematically collecting information from various alternative sources on the requirements of the labor market as regards ITS, the market of continuous education services satisfies needs for education services. This provides for a feedback effect, which helps to adjust the demand for education services in the IT sector to the needs of the labor market.

We should also take into account the characteristic feature of the problems relevant to the assessment of the imbalance between S and D at the micro level which consists in the fact that information for their resolution is derived from observing the states of S and D at various intervals and from different sources.

The task of managing the imbalance between S and D at the macro level is the elaboration of approaches and methods: 1) calculation of the composite demand and composite supply for IT jobs and qualifications; 2) the evaluation of the degree of occupational-skills mismatch between S and D which reflects conditions of ITS labor market.

The level of structural imbalance between S and D is directly related to the structure of unemployment on the one hand and is an indicator of the occupational-skills mismatch between the labor market and education services on the other. The size and character of the discrepancy provide an opportunity for elaborating an appropriate control mechanism.

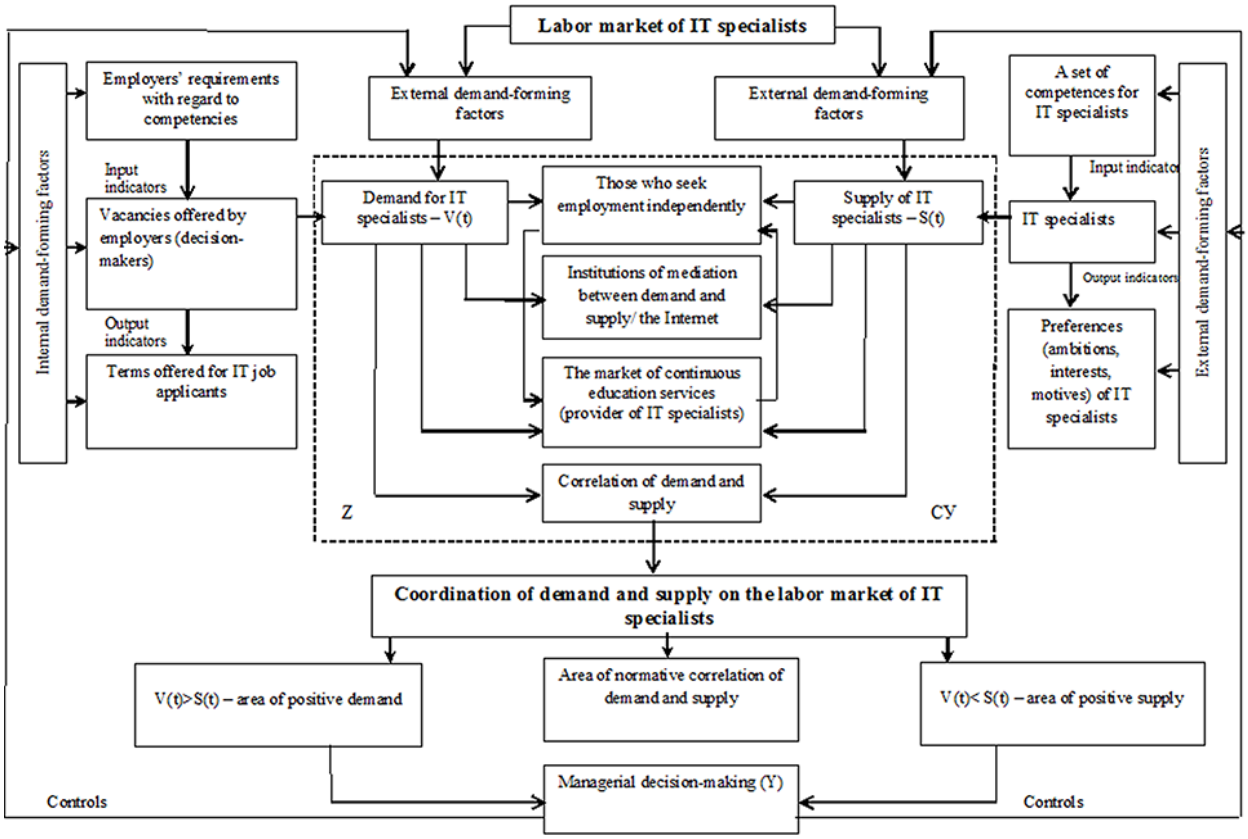

Fig. 1: Transaction scheme of the system of intelligent control of the market of IT specialists

Let $[t_1, t_2]$ be a specified amount of time. The volume and structure of the demand for specialists in various IT jobs and specializations will be described by vector $V[t_1, t_2] = \{V_1[t_1, t_2], V_2[t_1, t_2], ..., V_N[t_1, t_2]\}$ which presents a set of IT jobs broken down by sectors of a national economy within time interval $[t_1, t_2]$, where N is the number of IT jobs and specializations on the labor market.

The volume and the structure of supply of ITS in a specified time interval in terms of IT jobs and specializations can be described by the vector of supply $S[t_1, t_2] = \{S_1[t_1, t_2], S_2[t_1, t_2], ..., S_N[t_1, t_2]\}$.

The interaction of S and D on the labor market of ITS and the movement of resource flows occur predominantly on the basis of three sources.

Thus, the overall number of ITS with a certain occupational-skill structure which seek employment independently (through friends, relatives etc) can be described by vector $S^1[t_1, t_2] = \{S_1^1[t_1, t_2], S_2^1[t_1, t_2], ..., S_N^1[t_1, t_2]\}$. Let us designate the number of employed ITS from this category over time $[t_1, t_2]$ as $H^+[t_1, t_2]$, whereas

the number of job seekers as $H^{-}[t_1,t_2]$. These vectors can be described also in terms of the number of the employed as $H^{+}[t_1,t_2]=\{H_1^{+}[t_1,t_2],H_2^{+}[t_1,t_2],...,H_N^{+}[t_1,t_2]\}$ and those seeking employment, as $H^{-}[t_1,t_2]=\{H_1^{-}[t_1,t_2],H_2^{-}[t_1,t_2],...,H_N^{-}[t_1,t_2]\}$ in every IT job and specialization.

The overall number and makeup of ITS specialists who seek employment via the Internet and recruitment agencies will be designated as vector $S^2[t_1,t_2]=\{S_1^2[t_1,t_2],S_2^2[t_1,t_2],...,S_N^2[t_1,t_2]\}$.

Among them $W^{+}[t_1,t_2]$ is the number of the employed and $W^{-}[t_1,t_2]$ is the number of the unemployed. In terms of the occupational-skill structure the number of the employed and the unemployed IT experts is described by the following vectors:

$W^{+}[t_1,t_2]=\{W_1^{+}[t_1,t_2],W_2^{+}[t_1,t_2],...,W_N^{+}[t_1,t_2]\}$;

$W^{-}[t_1,t_2]=\{W_1^{-}[t_1,t_2],W_2^{-}[t_1,t_2],...,W_N^{-}[t_1,t_2]\}$.

The general number and the makeup of ITS who seek employment through the market of education services will be described by vector $S^3[t_1,t_2]=\{S_1^3[t_1,t_2],S_2^3[t_1,t_2],...,S_N^3[t_1,t_2]\}$.

Among them $Q^{+}[t_1,t_2]=\{Q_1^{+}[t_1,t_2],Q_2^{+}[t_1,t_2],...,Q_N^{+}[t_1,t_2]\}$ is the number and the occupational-skill makeup of the employed who entered the labor market through forms of training and retraining, whereas $Q^{-}[t_1,t_2]=\{Q_1^{-}[t_1,t_2],Q_2^{-}[t_1,t_2],...,Q_N^{-}[t_1,t_2]\}$ is the number and the occupational-skill makeup of the unemployed from this category who apply for IT jobs.

The constructed system of vectors allows one to describe the overall number and makeup of ITS on the labor market.

The unemployed part of ITS constitutes the vector of supply at a given moment t which can be described as follows: $S(t)=\{H^{-}[t_1,t_2]+W^{-}[t_1,t_2]+Q^{-}[t_1,t_2]\}$.

The overall number of the satisfied cases of S and D of ITS over certain period of time $[t_1,t_2]$ according to all the sources of interaction of S and D can be presented as $VIS[t_1,t_2]=\{H^{+}[t_1,t_2]+W^{+}[t_1,t_2]+Q^{+}[t_1,t_2]\}$.

Then the unsatisfied D at current moment in time t is calculated in the following way: $V(t)=V[t_1,t_2]-VIS[t_1,t_2]$.

The overall number of satisfied cases of supply and demand in individual IT jobs and specializations over certain period of time $[t_1,t_2]$ according to all the sources of interaction between S and D can be calculated using the following equations:

$V_1(t)=V_1[t_1,t_2]-VIS_1[t_1,t_2]$,...,

$V_N(t)=V_N[t_1,t_2]-VIS_N[t_1,t_2]$;

$S_1(t)=S_1[t_1,t_2]-VIS_1[t_1,t_2]$,...,

$S_N(t)=S_N[t_1,t_2]-VIS_N[t_1,t_2]$.

3.7.1. Conditions of the labor market of ITS

The interaction between S and D of ITS forms the conjuncture of the respective segment of the labor market – the real situation that emerges on the labor market in the process of interaction of S and D (purchase-and-sale of the labor force) under the influence of numerous factors, including political, socio-economic, demographic, migration and other ones ("Conjuncture of the labor market").

According to the conjuncture of the labor market, the latter has three states: equilibrium, labor deficit and labor excess ones. In practice, the general quantitative and structural equilibrium (balance, coordination) of S and D of the labor force are not easily achieved. The conditions of the labor market exert immediate influence on the price of labor (remuneration), which, in turn, varies depending on conditions on the market.

Let us consider market conditions in the context of the IT segment. Thus, 1) if at moment in time t vector of demand $V(t)$ exceeds vector of supply $S(t)$, i.e. the composite demand for ITS in various IT professions and specializations is higher than the composite supply in terms of the specified jobs and specializations $V(t)>S(t)$, then there is a deficit of IT specialists on the market; 2) if at moment in time t vector of supply $S(t)$ exceeds vector of demand $V(t)$, i.e. the composite supply of specialists in various IT jobs and specializations is higher than the composite demand for ITS in terms of the IT jobs and specializations in question $V(t)<S(t)$, then the labor market has an excess of ITS; 3) if at moment in time t vectors of supply $S(t)$ and demand $V(t)$ coincide, i.e. the number and makeup of S of ITS are equal to the number of IT vacancies for specialists of appropriate qualifications and specializations are sought, then we can speak of an ideal situation of balance $V(t)=S(t)$ on the labor market.

The description of the labor market's conjuncture by means of the three above mentioned states does not allow to reveal the entire range of interrelations between S and D of ITS. For instance, a gap between S and D can be quite substantial (critical) or, on the contrary, insignificant. It is also necessary to note the character of the tendencies of growth and

diminishment of imbalance from the perspective of supply and demand. The variety of possible states of S and D generates a respective set of conjuncture situations on the labor market of ITS. This, in turn, predetermines the need for prompt decision-making in every specific case aimed at decreasing the imbalance between S and D.

3.7.2. Approaches to minimizing the imbalance between S and D on the ITS' labor market

The experience of developed market economies (Doucek et al., 2012; *Forecast and Anticipation for Skills Supply and Demand in ETF Partner Countries*, 2013; Pouliakas, 2014; Wennergren, 2007) shows that full coincidence of S and D on the labor market is impossible. The labor market is always uncertain because of the permanent delay of potential S and D(Sigova, 2011).

The most widespread vector form of the ideal criterion function of the discordance between S and D on the labor market is the following: $V(t) - S(t) \to 0$ .Researchers and practitioners most often try to minimize the difference between the vectors of S and D. Depending on the social policies of a country in question and the level of its economic development various criteria of optimal functioning of the labor market are formulated. The most widespread among them is the maintenance of the economically justifiable minimal ("natural") level of unemployment and the optimal level of employment. There are various approaches to formalized description of the notion "optimal unemployment level". According to the conceptual scheme of the functioning of the labor market which was adopted by the authors, the mechanisms of regulation (received control) and self-regulation must change the flow of S and D of ITS in such a way as to achieve their minimal imbalance. This implies that the received control at this level of D (number of vacancies) and S (number of the unemployed and job-seeking ITS) must ensure a maximal overall level of recruitment:

$$VIS[t_1, t_2] = \left\{H^+[t_1, t_2] + W^+[t_1, t_2] + Q^+[t_1, t_2]\right\} \to \max$$

We may also consider the achievement of the coordination of S and D on the ITS' labor market in terms of makeup. In this case it is necessary to strive towards achieving maximal recruitment in every specific IT profession and specialization, i.e. $\max D = \max\{VIS_1(t) + VIS_2(t) + \ldots + VIS_N(t)\}$.

The indicator of the balance of supply and demand on the IT experts' labor market can be described from the perspective of supply, i.e. the attainment of a minimal unemployment level, which is generally defined as: $S(t) = \left\{H^-[t_1, t_2] + W^-[t_1, t_2] + Q^-[t_1, t_2]\right\} \to \min$.

We may also introduce the notion of balance from the perspective of achieving the minimal level of structural unemployment over a certain time period which can be defined as a minimum of composite imbalance in various IT jobs and specializations:

$$\min D^* = \min\{(V_1(t) - VIS_1(t)) + (V_2(t) - VIS_2(t)) + \ldots + (V_N(t)) - VIS_N(t)\}$$

In order to implement the specified scheme of the functioning of the labor market, it is necessary to indicate sources of necessary information and a procedure of assessment for all of its components. This information is provided by the national statistical bodies, national reviews of the labor force, budget inspection of households and results of the alternative research of the labor market, and also on the basis of regular surveys and sampling observations (Borisov and Alekseyev, 1982).

3.8. Method of assessing the degree of imbalance between S and D with the help of a fuzzy scale of discordance

In order to obtain generalized characteristics of the correlation of S and D on the market of ITS within time interval $[t_1, t_2]$, let us introduce the notion of "indicator of quantitative imbalance", which represents the ratio of the number of the unemployed and job-seeking ITS (supply) to the number of IT jobs:

$\delta = S[t_1, t_2] / V[t_1, t_2]$, if $S[t_1, t_2] < V[t_1, t_2]$, and $\delta = V[t_1, t_2] / S[t_1, t_2]$ if $S[t_1, t_2] > V[t_1, t_2]$.

Let the indicators which describe the labor market of ITS be data-based and the above formulas (1) and (2) provide for calculating the values of S and D. As a rule, factual data for assessing supply and demand come from different information sources. These data are not ideal, far from comprehensive and not free from subjectivism and contradictions. Therefore it appears logical to examine the indicator of the "imbalance between supply and demand" as a linguistic variable. Depending on the value of deviation (imbalance) of S and D, every degree of the state of imbalance can be verbally expressed by such linguistic terms as optimal imbalance, minimal imbalance, acceptable imbalance, complete imbalance of S and D. It is proposed to describe the range of variation of the imbalance of S and D of ITS

as a mismatch scale consisting of two segments, one of which we will call a region of positive demand (in case of the latter's dominance over supply) and the other a region of positive supply in the contrary case. Information on the degree of imbalance on the mismatch scale represents expert assessment in the form of membership functions of fuzzy sets obtained by means of the experts' projection of the above mentioned verbal gradations (values) of the linguistic variable "imbalance between S and D" on the universal fuzzy scale represented by segment [0,1]. Point 0 corresponds to the unsuitable value of quantitative characteristic of imbalance, i.e. represents complete imbalance of S and D, whereas point 1 represents the state of balance of S and D, i.e. ideal correlation between them. In order to formally describe verbal parameters, experts determine relevant linguistic and fuzzy valuables, base sets and membership functions of fuzzy variables, during the specification of which direct and indirect methods are applied (Borisov & Alekseyev, 1982; Melikhov et al., 1990; Yager, 1986; Zadeh, 1975). In applying direct methods, the degree of membership of elements $x \in X$ can be set by one expert or a group of experts. In case of one expert, he/she assigns degree of membership $\mu_l(x) \in [0,1]$, which in their opinion best agrees with the notional interpretation of the fuzzy set, for every verbal gradation $l = \overline{1,m}$ of linguistic variable "imbalance between S and D".

Fig. 2 illustrates a mismatch scale which shows imbalance between S and D. As can be seen in the Fig., each of the specified regions of changes in the imbalance $[E, A]$ and $[E^*, A]$ is an interval [0,1] divided in conformity with a possible mismach degree between S and D into several segments, which are regions of deviation from the standard value of the imbalance.

In order to formalize the parameters determining the degree of imbalance between S and D at a certain moment in time, let us use functions $s(S_j)$ described as fuzzy measures and being a real number which an expert assigns to every event S_j. These functions were introduced in the work(Sugeno, 1974)for assessing the measure of uncertainty. For $\forall i$, functions $s(S_j)$ characterize the degree of the expert's confidence that $s(S_j) \subset \Psi_S$. The scope of changes in the imbalance depending on the degree of its expressiveness, i.e. semantic interpretation of verbal gradations can be divided , by expert assessment, into several fuzzy intervals representing the region of the change of functions of membership of fuzzy sets of verbal gradations of the linguistic variable "imbalance of S and D" δ_i, specified for the set of real numbers R_δ in the shape of

$$\mu_{\delta_i} : R_\delta \to [0,1].$$

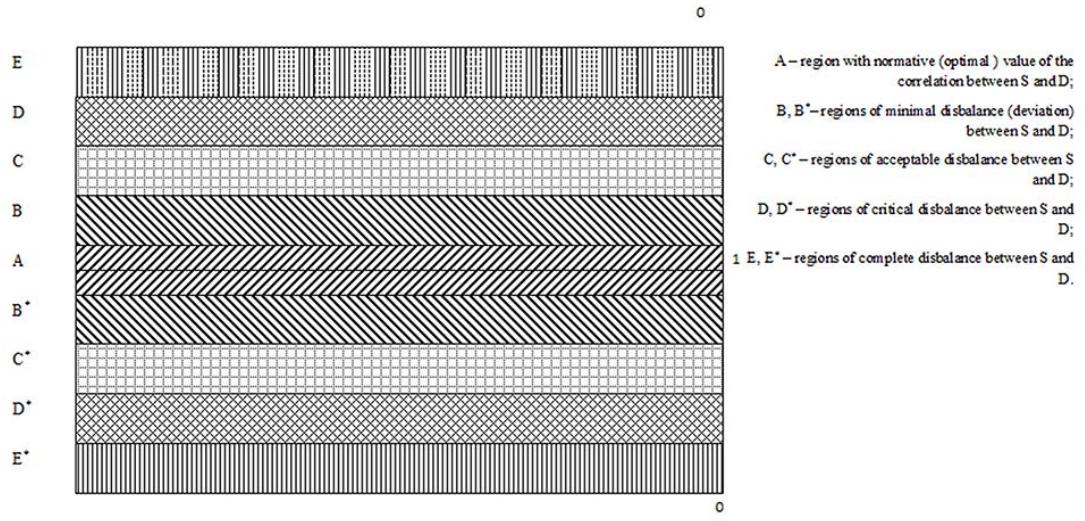

Fig. 2: A graphic illustration of the degree of imbalance between S and D

Thus, for instance, in an expert's opinion, the scope of changes in the degree of membership in the interval [0.8;1] can correspond to the standard value of the imbalance between S and D, wheras complete imbalance betweenS and D can occur in case of the membership functions' values falling into range [0; 0.2) (Table 1).

Let us express the guideline value of imbalance (optimal correlation between supply and demand) at the moment in time t^m (or in certain time period) by

$\delta^{t_m}{}_{norm} = S^{t_m}{}_{norm} / V^{t_m}{}_{norm}$ if $S^{t_m}{}_{norm} < V^{t_m}{}_{norm}$ and $\delta^{t_m}{}_{norm} = V^{t_m}{}_{norm} / S^{t_m}{}_{norm}$ if $S^{t_m}{}_{norm} > V^{t_m}{}_{norm}$.

If running values of supply and demand are known (as is their correlation (the running disbalnce)), i.e. $\delta_{cur}{}^{t_m} = S^{t_m}{}_{cur} / V^{t_m}{}_{cur}$, then the membership functions of the current state of imbalance can be established using the following:

$$\mu_l(x) = 1 - \left| \delta_{cur}^{t_m} - \delta_{norm}^{t_m} \right|. \quad (3)$$

Table 1: The region of changes of the function of membership of fuzzy sets of verbal gradations of the imbalance between S and D, including in terms of various IT jobs and specilaizations

	Terms – verbal (fuzzy) values of the degrees of linguistic variable "imbalance between S and D"	Scope of changes of terms on the scale of discordance
Imbalance between S and D	Optimal (standard) imbalance between S and D	[0.8;1]
	Minimal imbalance	[0.6;0.8)
	Acceptable imbalance	[0.4;0.6)
	Critical imbalance	[0.2;0.4)
	Complete imbalance between S and D	[0;0.2)

As is seen in Fig. 1, the imbalance between S and D may vary over a wide range: from the standard value of the correlation of S and D to their complete imbalance. The closer the running imbalance is to the standard one, the more favorable the region of changes is in which the values of membership functions of the current state occur.

Fuzzy classification of the states of imbalance according to the degree of its expressiveness at a certain moment in time can be established according to the following algorithm:

1. Establish a set of verbal parameters of the linguistic variable "imbalance between S and D" which reflects the classes of fuzzy states of the imbalance.
2. To establish a region of variation of the membership functions of fuzzy sets of the degrees of imbalance for every class of fuzzy sets.
3. To generate appropriate controls in the form of production rules for every class of fuzzy sets of imbalance in accordance with the values of the membership functions within the region of their variation with the use of expert knowledge.
4. To establish the discordance (deviation) between the current state and the standard value of the imbalance for every assessed time period according to formula (3).
5. To establish the class to which the analyzed state of imbalance belongs according to the value of discordance between S and D and the value of the relevant function of membership.
6. To obtain a production rule from the knowledge base depending on the class in which the values of imbalance between S and D occur.

4. Discussion

We conducted an analysis of the labor market of ITS and substantiated the importance of elaborating approaches, models and methods of coordinating S and D in the IT sector, which take into account the specifics of the IT labor market and the preferences of its individual actors, i.e. ITS and employers.

The notion "intelligent control of S and D on the labor market of ITS" is introduced which implies adoption of the best managerial decisions for the minimization of the imbalance between S and D of ITS.

We identified the components and generalized model of the intelligent system of control of the ITS' labor market and formulated the problem of coordinating S and D of IT specialists in general.

We examined the levels of modeling the processes of interaction of S and D on the ITS' labor market, identified the problems of assessing the correlation between S and D from the viewpoint of their effectiveness which is expressed by the degree of balance. We identified the types of S and D of ITS and defined the main areas of their coordination.

A method of managing a set of fuzzy reference states of D (search images of employers' expectations) and the real states of S (search images of ITS) at the microlevel based on fuzzy situation analysis and fuzzy automatic cognition was proposed.

We have elaborated a transaction model of the system of intelligent control of the labor market which provides for describing the interaction of vectors of S and D of ITS and the sources of movement of resource flows.

Methods of assessing structural discrepancies on the ITS' labor market, the degree of imbalance between S and D of the latter on the basis of a fuzzy scale of discordance, an algorithm of fuzzy classification of the states of imbalance.

5. Conclusion

The imbalance between S and D on the labor market at present is one of the most pressing issues in global economy. In addition to quantitative and structural aspects of the discrepancies on the labor market, the problem of eliminating skills imbalance

has become particularly important recently. This problem is exacerbated by the high fluidity of the IT sector.

At present the Institute of Information Technology of the National Academy of Science of Azerbaijan is engaged in designing an intelligent system of managing the labor market of ITS which is based on the methodological and conceptual approaches advanced in this paper. The system is meant to reduce the quantitative and qualitative imbalance between S and D on the ITS' labor market by means of providing information and consultation support for decision-makers at various levels of administration as well as for employers and ITS, in identifying the current needs of the labor market and the education services in the IT sector, the adoption of executive decisions adequate to the situation as regards balancing S and D, the management of human resources in the IT sector, continuous adjustment of decision-making to the changing business environment.

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