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Fuzzy approach to estimate the demand and supply quantitative imbalance at the labor market of information technology specialists

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Abstract: This document considers the processes of modelling supply and demand interactions in the labour market for information technology experts (IT professionals) and management of their quantitative disparity at the macro level. The types of supply and demand imbalance for IT professionals are marked out. The methods are proposed for estimating the structural mismatch in the labour market for IT professionals, the degree of supply and demand imbalance for IT professionals based on fuzzy unbalance scale. The algorithm of fuzzy classification of states of imbalance is proposed.

Keywords: *labour market for IT professionals, supply-demand balancing, quantitative imbalance, fuzzy mismatch scale, fuzzy classification of states of imbalance.*

1. Introduction

The supply and demand mismatch in the labour market today is one of the most pressing problems in the world. In the field of information technology, this problem is even more complicated. High dynamics of the ICT sector, global informatization, rapid technological change, rapid obsolescence of knowledge and, consequently, of the content and structure of IT professions and specialties cause the imbalance in volume and structure of incoming and outgoing flows in the labour market for IT professionals. This in turn leads to supply and demand mismatch for the latter both in professional qualification and quantitative perspective [1–5]. Depending on the qualitative and quantitative aspects the imbalance of supply and demand for IT professionals has different forms, can be viewed at different levels (microfocus or macrofocus) and requires the use of appropriate approaches to its reduce.

2. The evolution of the approaches towards determination of staff demand and supply-demand balancing in the labour market

The continuously varying economic situation, the movement of countries towards innovation-driven growth of the economy cause the change in the requirements for IT-profile jobs, expand of IT professions and specializations content and introduction of new ones. This in turn leads to the formulation of new competence requirements to IT professionals (the profile of professional skills) by employers, and causes a need to determine the demand for competence of the latter by way of qualification requirements for IT profile jobs. The competences considered through the prism of formal qualifications of IT professionals are a tool aggregating professional profiles, individual experience, personal and other qualities of the latter, as well as determine their employment opportunities, career growth, self-confidence, etc. The competences are also important factors and mechanism in the development and harmonization of labour, education and economic development policies. The challenges faced by the labour market for IT professionals specify new demands to the educational system. The essence of these requirements reduces to creating conditions that allow determining the qualifications of graduates by recognizing learning outcomes as set of skills and knowledge obtained during the mastering of educational programs, relevant to the employer's qualification requirements to IT profile workplace rather than by recognizing of a course taken.

The urgency of the problem of noncompliance of electronic skills (professional knowledge, expertise, experience, etc.) of IT professionals formed by educational institutions with e-skills that are in demand in the labour market, contributed to launching of a number of initiatives and research in this field [6–11].

Naturally, for each type of imbalance or their combination there will be different decisions on the development of appropriate control actions towards balancing of supply and demand for IT professionals. Thus, depending on the current labour market situation and in accordance with the anticipated needs of forming an innovative economy the control actions may be directed towards harmonization of:

a) quantitative characteristics (eliminating shortage or excess of IT personnel);

b) qualitative characteristics (obsolescence of professional skills);

c) the level of training of IT professionals (superior or insufficient skills);

d) the structure of training of IT professionals (deficit or surplus of IT professionals of certain specialization, obsolescence of one and the emergence of other IT professions and specialties);

e) various combinations of the above mentioned types of imbalance.

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In the study of processes of supply and demand balancing it is also necessary to identify the level of the imbalance assessment. It can be:

1) microfocus, that includes individual level (IT specialist), the level of employer (company) [12–16];

2) macrofocus, that includes the levels of industry (sector, segment) or the entire economy [17, 18].

3. Task Description

For the general characteristics of supply and demand ratio in the labour market for IT professionals in a time interval $[t_1, t_2]$ we introduce:

1. the scope and pattern of demand for IT professionals in the terms of IT professions and qualifications we shall describe with the vector

$$V[t_1, t_2] = \{V_1[t_1, t_2], V_2[t_1, t_2], ..., V_N[t_1, t_2]\},$$

representing the variety of IT vacancies by the branches of the national economy in a timeframe $[t_1, t_2]$, where N is a number of IT professions and qualifications available in the labour market.

2. the scope and pattern of supply for IT professionals in designated timeframe in the terms of IT professions and qualifications may be characterized with the supply vector

$$S[t_1, t_2] = \{S_1 [t_1, t_2], S_2[t_1, t_2], ..., S_N[t_1, t_2]\}.$$

3. the concept of "quantitative imbalance index", which defines the ratio of the number of unemployed and IT professionals who are seeking for a job (supply) to the number of IT-profile jobs:

$$\delta = S[t_1, t_2] / V[t_1, t_2] \text{ if } S[t_1, t_2] < V[t_1, t_2]$$

and

$$\delta = V[t_1, t_2] / S[t_1, t_2] \text{ if } S[t_1, t_2] > V[t_1, t_2].$$

Typically, the actual data for the evaluation of supply and demand come from various sources. This information is not perfect, far from complete and is not lacking in subjectivity and inconsistency. Therefore it seems to be natural to consider the index of "supply and demand imbalance" as a linguistic variable.

Depending on the degree of the supply and demand perturbation (mismatch) each imbalance gradation can be verbally expressed with such linguistic terms as optimal imbalance, minimum imbalance, allowable imbalance, ultimate imbalance and complete imbalance of supply and demand. It is proposed to describe the range of variation of supply and demand imbalance for IT professionals in the form of a mismatch scale that consists depending on the degree of superiority of demand over supply, or, on the contrary, of supply over demand, the two segments, which we call the area of positive demand in the case of the superiority of the latter over the supply and, otherwise, the area of positive supply. Information on the imbalance degree in the mismatch scale is expert assessments in the form of membership function of the fuzzy sets derived by experts through mapping of above mentioned verbal gradations (values) of the linguistic variable of "supply and demand imbalance" onto the universal fuzzy scale represented by the interval [0,1].

Here, the point 0 corresponds to unacceptable value of quantitative imbalance characteristics, i.e. reflects a complete imbalance of supply and demand, and point 1 corresponds to the equilibrium of supply and demand, i.e., reflects the ideal ratio of the latter. For a formal description of verbal parameters the experts determined the appropriate linguistic and fuzzy variables, the basic sets and membership functions of fuzzy variables, in setting which the direct and indirect methods are used [19–22]. Under the direct method the membership degrees of $x \in X$ elements may be defined by one expert or a group of experts. In the case of one expert he put the each of $l = 1, m$ verbal gradations of linguistic variable "supply and demand imbalance" in correspondence with the degree of membership $\mu_l(x) \in [0,1]$, which in his view corresponds in the best way with to the semantic interpretation of a fuzzy set.

Figure 1 graphically illustrates the mismatch scale that reflects the supply and demand imbalance.

As is clear from the figure, each of these areas of imbalance changes $[E, A]$ and $[E^*, A]$ represents the interval [0,1], divided according to the possible mismatch degree of supply and demand in a number of segments – areas of deviation from the standard imbalance value.

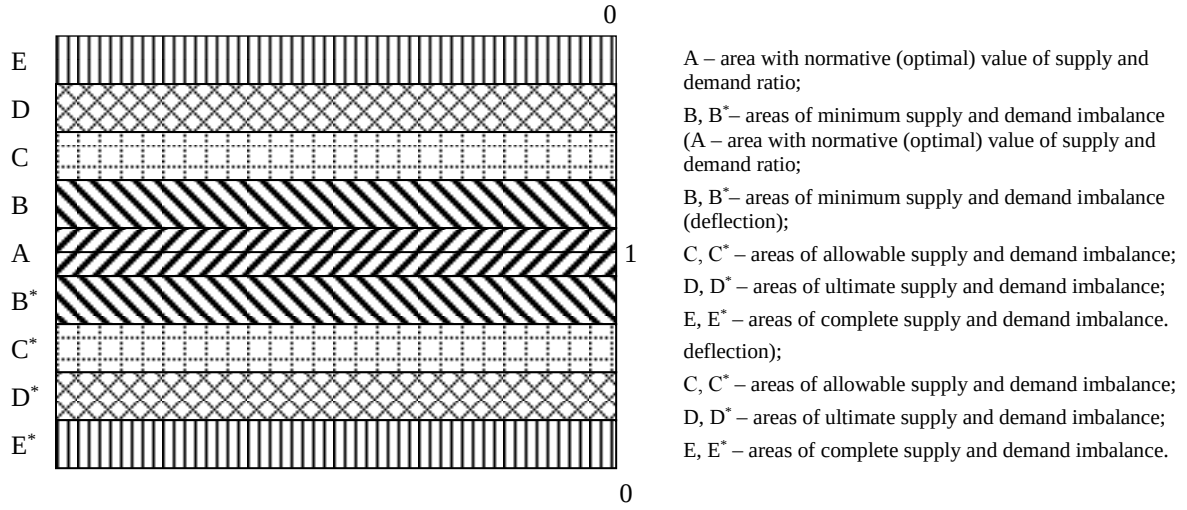

Figure 1.Graphic illustration of supply and demand imbalance degree

To formalize the parameters that determine the imbalance degree of supply and demand at some instant, we use the functions introduced in [23] to assess the measure of the uncertainty by the functions $s(S_j)$ called fuzzy measures and representing a real number which the expert put in correspondence with each S_j event.

For $\forall i$ function $s(S_j)$ characterize the expert's degree of certainty that $s(S_j) \subset \Psi_S$. Thus, the range of imbalance change depending on its manifestation degree, i.e. semantic interpretation of verbal gradations, can be divided via method of expert assessment into several fuzzy intervals, reflecting the variation range of the membership functions of the fuzzy sets of verbal gradations of linguistic variable "supply and demand imbalance " δ_i, defined in the set of real numbers R_δ as a function $\mu_{\delta_i} : R_\delta \to [0,1]$.

Thus, for example, from the expert point of view the range of the membership degrees in the interval [0.8, 1]may match the normative value of supply and demand imbalance, and the complete imbalance of supply and demand may occur in case of falling of membership functions values within the interval [0; 0,2) (Table 1).

Table 1. Variation range of membership functions of fuzzy sets of verbal gradation of supply and demand imbalance, including from a perspective of certain it professions and specialties

	Terms – verbal (fuzzy) assessment of linguistic variable "supply and demand imbalance" gradations	Range of terms variation on the imbalance scale
Supply and demand imbalance	Optimal (normative) supply and demand imbalance	[0,8;1]
	Minimum imbalance	[0,6;0,8)
	Allowable imbalance	[0,4;0,6)
	Ultimate imbalance	[0,2;0,4)
	Complete supply and demand imbalance	[0;0,2)

Let us set the normative value of imbalance (the optimal supply and demand ratio) at the time moment t^m (or in certain time segment) through

$$\delta^{t_m}{}_{norm} = S^{t_m}{}_{norm} / V^{t_m}{}_{norm}, \text{ if } S^{t_m}{}_{norm} < V^{t_m}{}_{norm},$$

and

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

If the current values of supply and demand are known and, respectively, their ratio (current imbalance), i.e.

$\delta_{cur}{}^{t_m} = S^{t_m}{}_{cur} / V^{t_m}{}_{cur}$, then the membership functions on the imbalance scale may be determined through the following formula:

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

As it`s clear from the Figure 1, the supply and demand imbalance may vary in a wide range: from the normative value of supply and demand ratio to their total imbalance. The closer is the value of the current imbalance to the normative the more favorable is the range of variation the values of the membership functions of the current state fall in.

4. The algorithm of fuzzy classification of states of imbalance

This approach to assessing the labour market situation allows making fuzzy classification of its states according to the degree of supply and demand imbalance.

Fuzzy classification of imbalance states depending on its intensity at a particular time moment can be determined according to the following algorithm:

1. To define a set of verbal parameters of linguistic variable of "supply and demand imbalance" reflecting the classes of fuzzy state of imbalance.
2. For each class of fuzzy mismatch states to determine the variation range of the membership functions of the fuzzy sets of gradation imbalance.
3. To generate the appropriate control actions in the form of production rules for each class of fuzzy imbalance states in accordance with the values of membership functions within their variation range and using expert knowledge.
4. For each estimated time slice to determine the mismatch (deflection) between the current and the standard value of imbalance using formula (1).
5. In accordance with the mismatch of supply and demand and the value of the corresponding membership functions to set the class to which the investigated state of imbalance refer.
6. Depending on the class in which demand and supply deflection rates fall, the activation of condition-action rule from the knowledge base, corresponding to the desired management decisions.

For example, the control actions generated in the form of condition-action rules in an open knowledge base, depending on the class into which they are incorporated, may relate to elimination of discrepancies between supply and demand in the context of filling quantitative shortage of IT professionals, including in particular IT occupations and professions, or coordination of structural imbalance of IT professionals. Then production rules may affect the qualitative aspects of the supply and demand imbalance associated with obsolescence of IT skills, with emerging and the need to eliminate the factors suppressing the IT sector growth. Another class of control rules can be associated with policies in the field of continuing education and training (retraining, upgrade qualifications, additional education) aimed at suppressing the supply and demand mismatch. Yet another class of rules may reflect measures on expanding and creating new innovative IT-profile jobs, developing the necessary human resources, adaptation of IT education system to the IT professionals market needs, developing mechanisms for coordination of stakeholders' activity in the labour market for IT professionals etc.

5. Conclusion

Approaches that are proposed in the article towards modelling supply and demand interaction in the labour market for IT professionals and management of their quantitative mismatch at the macro level, the degree of supply and demand imbalance based on fuzzy mismatch scale, fuzzy classification algorithm of imbalance states, the approaches to the formation of a knowledge base in the form of production rules that describe the dependence of the adoption of one or another management decision on the value of supply and demand mismatch are one of the possible options for matching supply and demand in the quantitative terms and can support various person concerned in making informed

decisions on management of imbalance in the labour market for IT professionals.

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