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Development of information technology to identify the imbalance between labor and educational services markets in the construction sector

I V Udovenko[1*], T V Zaitseva[1] and N P Putivzeva[1]

[1]Institute of engineering and digital technologies, Belgorod State National Research University, Pobedy St., 85, Belgorod, 308015, Russia

E-mail: udovenko@bsu.edu.ru

Abstract. The paper analyzes the current state of the labor market in Russia, shows the need to improve mathematical and software tools for managing the regional human resources potential and the imbalance between the labor markets (LM) and educational services market (ESM), and suggests an approach to building a model for identifying criteria that affect LM and ESM in the construction sector on the example of the Belgorod region. The features of the development of the construction sector in the Belgorod region are considered. Based on the analysis of the collected statistical data and expert judgments, groups of criteria and criteria in each group that affect the amount of imbalance are identified. A generalized model for determining the balance between LM and ESM is constructed in the form of a system of equations. The paper presents a model of interaction between markets in the form of criteria and their groups, which allows determining the imbalance between the labor and educational services markets in the Belgorod region. The developed software tools are presented for determining the most influential criteria and their groups, as well as for the initial calculation of the imbalance. The program sets the number of groups of criteria and the number of criteria in each group. The following matrices are filled in: probabilities of criteria influence, criteria significance, criteria signs. The values of influence and weights for groups of criteria, minimum and maximum values for groups, and the imbalance between LM and ESM are calculated.

1. Introduction

To determine the level of socio-economic and scientific-technical development of regions, indicators are used that reflect the raw material and material-technical base available in them, as well as taking into account the demographic situation and the current state of regional labor markets (LM) and the educational services market (ESM). The peculiarity of these markets is that they are constantly changing, hardly subject to state regulation, and the processes of interaction between LM and ESM among themselves and with the external environment are extremely complex and non-stationary. For many areas, there is a discrepancy between the demand for jobs and the vacancies presented on the exchange. This discrepancy leads to a decrease in the quality of life in the regions, an increase in the percentage of the population with incomes below the subsistence minimum, and an increase in the number of unemployed. This year, quarantine measures led to the closure of a large number of organizations, an increase in the number of people standing on the labor exchange, and increased the previously existing imbalance between LM and ESM. This situation is currently typical for many industries. In the construction sector, there is also a shortage of highly specialized specialists, and there is a discrep-

ancy between the specialization of graduates and the professions in demand. The construction industry is experiencing an era of innovation and modern technologies in the construction and finishing of buildings and structures, which in turn requires a large number of architects and design engineers, which leads to the need to provide continuing education, open new master's and postgraduate programs to train the currently required specialists, and a number of other measures to reduce the imbalance between markets. In order to manage effectively dynamically changing complex socio-economic objects, it is necessary to collect and process huge amounts of heterogeneous information of varying degrees of aggregation, perform forecasting and form scenarios for the development of the studied processes, and develop mechanisms for managing changes in the situation in the LM and ESM [1]. To do this, it is necessary to monitor the state of both the CRC as a whole and its individual elements, which implies the development and/or improvement of mathematical methods and models, as well as the use of it and computer modeling [2, 3].

Issues of managing changes in labor and educational services markets are covered in the works of many national and foreign scientists, for example: M. Albert, S.V. Andreev, A.S. Bolshakov, V.R. Vesnin, M.V. Glazyrin, V.A. Dyatlov, B.L. Eremin, J. Ivantsevich, A.Ya. Kibanov, A.L. Kuznetsov, A.A. Lobanov, A.V. Mamatov, V.I. Matirko, M.Kh. Meskon, A.V. Molodchik, V.I. Nekrasov, E.V. Okhotsky, A.I. Turchinov, F. Khedouri, V.I. Shkatulla, and others [4, 5]. However, the main attention of the authors is directed to the study of the specifics of the processes of managing the existing personnel of the enterprise, which is only part of the CRC. Today, there are no effective tools to assess and predict the existing and emerging imbalance between the labor and educational services markets, and to ensure its scientifically based regulation, taking into account the dynamics and complexity of their interaction with the external environment, and the characteristics of the territory [6].

2. Materials and methods

The existing approaches to determining the imbalance between the labor and educational services markets, and proposals for managing the existing imbalance were analyzed [7,8]. The authors propose a model of market interaction that includes the following elements (Fig. 1, 2):

- labor market;
- educational service market;
- 5 groups of criteria [9];
- management impact;
- set of external factors.

Figure 1 shows a model that examines the interaction of markets, taking into account the influence of environmental factors through the direct influence of criteria and their groups on each of the markets.

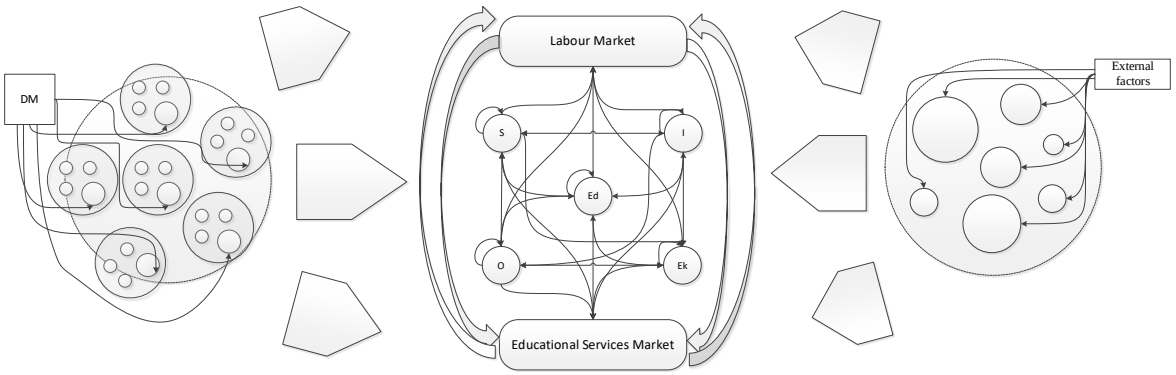


Figure 1. Generalized model of market interaction with consideration for the influence of environmental factors.

Figure 2 shows a model that takes into account not only the direct impact of criteria and their groups on each of the markets, but also the indirect impact of criteria on other criteria, both within and outside the group.

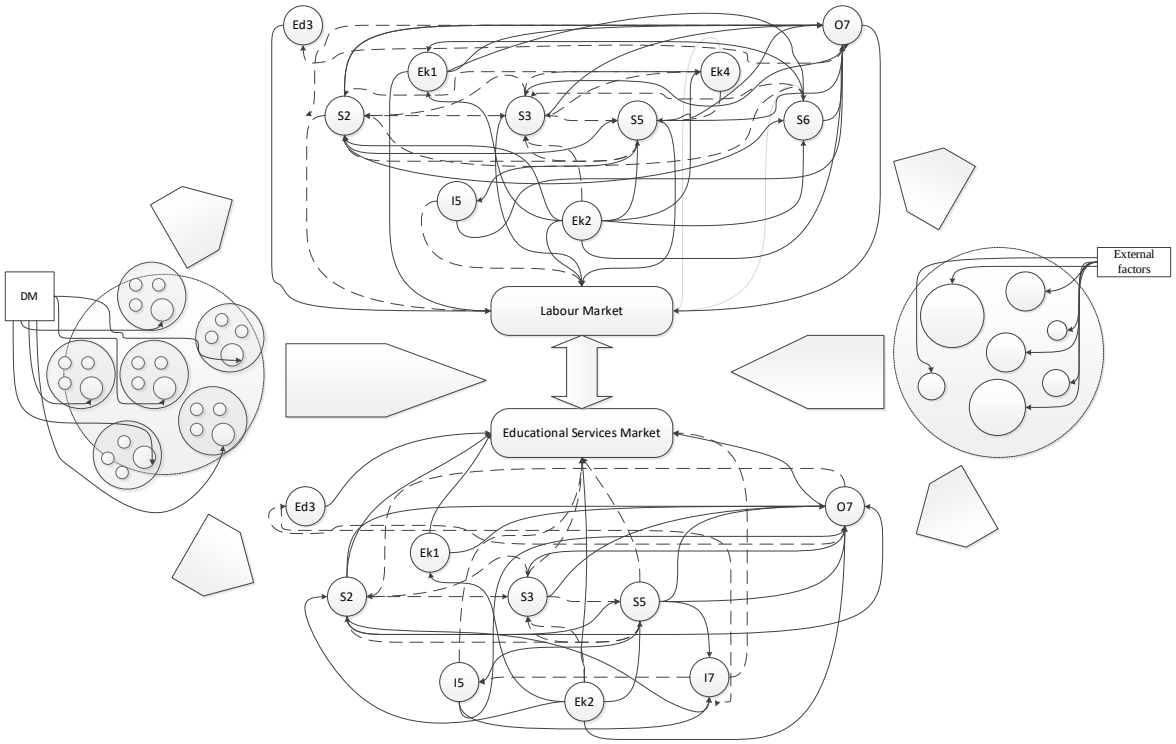


Figure 2. A model of interaction between markets as a system of criteria and their groups taking into account the influence of environmental factors.

Analysis of the state of the modern labor market in the Russian Federation shows that, firstly, it is characterized by an imbalance between the demand and supply of labor (the presence of unemployment above the natural rule); secondly, there is a significant demand for highly qualified labor [10, 11]. One of the areas of the economy where the imbalance is characterized not only by a significant excess of one of the markets, but also by a dynamic change in values during the year, is construction.

For example, we will consider the specifics of the development of the construction sector in the Belgorod region, which is also a border region. The development of construction production in the Belgorod region creates favorable prospects for a stable leading position of the Belgorod region on construction sites in Russia. For a number of years, the Belgorod region has been among the top ten regions of the Russian Federation in terms of the volume of housing commissioned per inhabitant, and it ranks second among the regions of the Central Federal district after the Moscow region. In the region, industrial and socially significant facilities are being built, settlements are being improved, and work is underway in the field of construction of individual housing and road infrastructure. The positive features of the construction sector in the Belgorod region include support and creation of conditions for strengthening new small construction companies in the market. To strengthen their position in the market, small construction companies simplify the procedure for entering the market and reduce duties on the supply of construction materials. In order to support certain groups of construction companies, they reduce taxes and provide them with benefits. Production efficiency increases, including through the modernization of construction technologies and technological transformations of the construction sector as a whole [12].

To determine the nature of the impact of factors on LM and EMS and the imbalance, statistical data were collected for the selected factors for the period from 2005 to 2019 to assess short-term development trends.

However, the cyclical components of these processes were not taken into account. This problem can be solved by the joint use of the formalized methods of applied statistics, probabilistic graphical-analytical methods and with the involvement of experts (if necessary).

As it is impossible to consider the dependence of each market on influencing factors in isolation to determine the degree of imbalance, it was decided to present the balance between LM and ESM as a system of equations, generally nonlinear [13]. It is impossible to solve analytically the resulting system, even in general terms, as, firstly, the number of variables greatly exceeds the number of equations, which at best will allow finding not one particular solution, but a set of solutions, and secondly, the presence in each of equations both linear and nonlinear dependence of the output variable from the underlying value of the criteria cannot be applied to the system nor the apparatus of simultaneous equations or iterative methods of solutions of systems of nonlinear equations. In this regard, it was decided to analyze the relationships between factors and groups of factors using a graph-analytical model [14].

3. Results

The obtained result is the basis for constructing mathematical models that reflect the mutual influence between factors within a group and the mutual influence between factors in groups, which allows developing possible scenarios for the development of a construction cluster, depending on the control actions that are changes in the identified factors.

Each of the markets considered in the study is a complex system in which it is necessary to take into account a large number of factors, some of which are “unchangeable” (change very rarely), some of which are “quasi – changeable” (that is, changed according to the schedule, regulations, etc.) from authorities at different levels (from local to state) and constantly changing depending on time and the current situation.

The developed methodology for assessing and predicting the balance between LM and ESM and the method were implemented to ensure adaptive management of the CRC of the construction cluster in the region. Based on the proposed methodology, a program was developed to determine the most influential and affected criteria and their groups, as well as to calculate the current imbalance between LM and ESM.

When loading the main program window, the user is prompted to select the number of criteria groups. The program provides that the number of groups is set by a number greater than or equal to 5, as the authors have identified 5 groups of factors [15]. In addition to the number of criteria groups, it is necessary to enter the number of criteria for each group (figure 3).

Next, a table (matrix) of criteria values (probability of influence and mutual influence of factors) is filled in, data is entered as a decimal fraction, and the nature of the influence of factors (positive or negative) is not taken into account. If they enter a factor value less than 0.01, the value in the cell is automatically reset to zero. After filling in the matrix, all empty cells are automatically filled in with zero values, and then fields are formed with the minimum and maximum values for each row and each column (Fig. 4).

The table shows that the maximum influence is exerted by factor B1 on B2 and factor C1 on B3. Factor C1 has the greatest influence on all factors, and factor B2 is the most dependent.

Next, the influence values for groups of criteria are calculated, as well as the minimum and maximum values for groups (Fig. 5). The table shows that the group of factors B has the greatest influence.

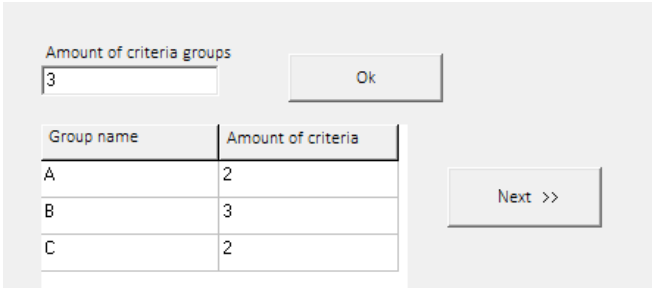
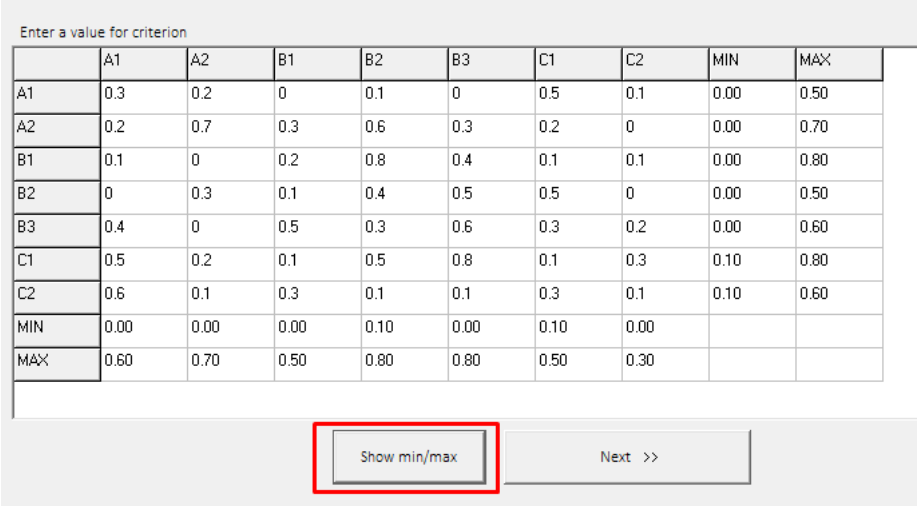
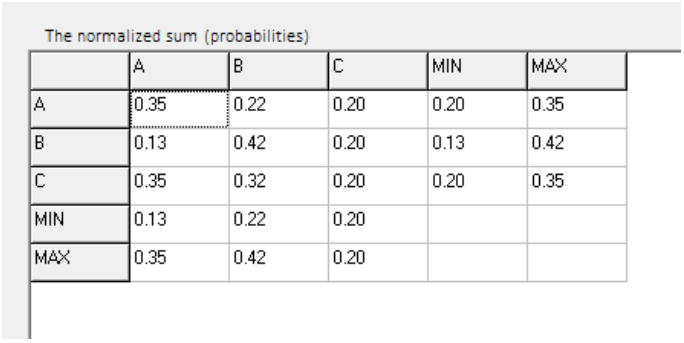


Figure 3. Determining the number of criteria in each group.



	A1	A2	B1	B2	B3	C1	C2	MIN	MAX
A1	0.3	0.2	0	0.1	0	0.5	0.1	0.00	0.50
A2	0.2	0.7	0.3	0.6	0.3	0.2	0	0.00	0.70
B1	0.1	0	0.2	0.8	0.4	0.1	0.1	0.00	0.80
B2	0	0.3	0.1	0.4	0.5	0.5	0	0.00	0.50
B3	0.4	0	0.5	0.3	0.6	0.3	0.2	0.00	0.60
C1	0.5	0.2	0.1	0.5	0.8	0.1	0.3	0.10	0.80
C2	0.6	0.1	0.3	0.1	0.1	0.3	0.1	0.10	0.60
MIN	0.00	0.00	0.00	0.10	0.00	0.10	0.00		
MAX	0.60	0.70	0.50	0.80	0.80	0.50	0.30		

Figure 4. Result of calculating the maximum and minimum values of criteria.



	A	B	C	MIN	MAX
A	0.35	0.22	0.20	0.20	0.35
B	0.13	0.42	0.20	0.13	0.42
C	0.35	0.32	0.20	0.20	0.35
MIN	0.13	0.22	0.20		
MAX	0.35	0.42	0.20		

Figure 5. Results of calculating values for groups of criteria.

The table (matrix) of weights of criteria (significance of factors) is also filled in, data is entered as an integer from 0 to 9. After filling in the matrix, all empty cells are automatically filled in with zero values, and then fields are formed with the minimum and maximum values for each row and each column. Next, the weights for the criteria groups are calculated, as well as the minimum and maximum values for the groups.

In the next step, the values of the product of the probability of each factor influence on its weight are calculated, and the minimum and maximum values of factors are calculated for each row and column. Values are computed intermediate matrices (matrix multiplication of probability of impact on its weight) to groups of criteria, and minimum and maximum values for the groups.

The next step is to complete the table of characters of the factors, when filling either 1 (in case of positive impact) or -1 (in case of negative influence factor). Next the final matrix (matrix of the integrated impact factors) is calculated with element-by-element multiplication of the cells in the interme-

diate matrix and the matrix of signs. The minimum and maximum values of criteria are also determined for each column and each row (Fig. 6), as well as for groups of criteria.

Outcome

	A1	A2	B1	B2	B3	C1	C2	MIN	MAX
A1	0.60	-0.20	0.00	-0.30	0.00	1.00	-0.10	-0.30	1.00
A2	-0.20	-4.90	0.60	-3.60	-0.60	0.20	0.00	-4.90	0.60
B1	0.00	0.00	-0.60	-4.00	2.00	0.70	-0.30	-4.00	2.00
B2	0.00	1.80	0.60	-1.60	1.50	2.50	0.00	-1.60	2.50
B3	-0.80	0.00	-2.00	-1.50	-0.60	-0.90	0.40	-2.00	0.40
C1	-1.50	0.40	-0.10	1.00	-3.20	0.00	1.20	-3.20	1.20
C2	-4.80	0.10	1.50	0.00	0.20	-0.60	-0.20	-4.80	1.50
MIN	-4.80	-4.90	-2.00	-4.00	-3.20	-0.90	-0.30		
MAX	0.60	1.80	1.50	1.00	2.00	2.50	1.20		

Figure 6. Result of final matrix calculations.

At the last step, the imbalance between the labor and educational services markets is calculated based on current information (Fig. 7).

Imbalance

LM	ESM	LM/ESM	LM-ESM	(LM-ESM)/LM
0.037	0.028	1.32	0.009	2.43

Figure 7. The imbalance calculation.

4. Discussion

Data analysis has shown that the following assumptions can be made when filling in the specified matrices:

1) If the influence of a factor on other factors or groups of factors differs slightly from zero, then we assume the influence value is zero.

2) If the probability of influence of a factor does not exceed 0.01, the weight of this factor is set to 1.

3) If the influence of a factor cannot be determined at the current time, then:

- if the factor was significant at the previous stage, the probability values of the factors and their weights are calculated as the average values within the group;
- if the factor was insignificant at the previous stage, then the value of the probabilities of the factors influence is set to infinitesimal.

4) If there are abnormal values that are not characteristic of the range of values of this factor during the temporary consideration of factors, then additional research is necessary to establish the reliability of the obtained values.

5) The probability values of the influence of a group of factors on another group, as well as their weights, are calculated as the average value for the corresponding block of completed probability and weight tables.

5. Summary

The proposed methodology and the tool developed on its basis allows defining the criteria of their group that have a significant impact on the imbalance between the LM and ESM in the construction industry, and other criteria, as well as to make a preliminary calculation of the imbalance on the cur-

rent values of criteria. This program also allows tracking how a change in one of the criteria affects both changes in other criteria and their groups, and changes in the imbalance as a whole.

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