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Methods of Establishing Occupational Skill Structure of Admissions in the System of Vocational Education

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ABSTRACT

The purpose of the study is to determine the business need for vocational training. This article gives a detailed analysis of the problem aimed at finding optimal occupational skill structure of training, which involves all kinds of positive effects in various areas of public life – from the economy up to the spiritual sphere of human life. Moreover, the authors described relevant stages and their interconnections in the implementation process and provided a detailed description of relevant source data. The practical value is that the investigation suggests approaches to provide balance in the regional labor market, and considers the need for concerted action of regional authorities, educational and manufacturing companies in the region.

KEYWORDS
Regional socio-economic development, labor market, vocational training system, determining the structure of professional qualifications, system-dynamic modeling.

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Introduction

The post-industrial economy of the XXI century is characterized by high mobility: there are new professional activities, associated with the development of digital technologies; some engineering specialties lose their paramount importance taking a “back seat” (Athique, 2016; Davidson & Sly, 2013; Zenou, 2015).

Development of the "correct" forecast of business need for vocational training presents a task, which solution is common for the interests of employers, university management, parents and applicants themselves (Parks, Olson & Bokor, 2015; Giovannelli & Proietti, 2016). In addition, forecast is an important part of marketing information required for regulation and monitoring of changes in the educational industry (Bleikh & Young, 2016).

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Adequate forecast of business need for vocational training increases economic efficiency, social stability, and prosperity in the spiritual realm (Mukhametshina, Bulatov & Antonova, 2014; Kosorukov, 2015). These beneficial effects stem from the balance in the number of available experts in a particular specialty and the business need for workers.

Literature Review

As noted in many studies, foreign methodology is characterized by various approaches to labor demand forecast, however their common feature implies its differentiation with respect to national, regional, local and sectoral levels; selection of total employment components and consideration of their changes (Scanlon & Holt, 2014; Rasdorf, Hummer & Vereen, 2016). In this regard, research papers (Lindley & Machin, 2014) revealed patterns of employment change in the selected groups of working-age population, generated by skill level, depending on cyclical changes in economic activity and technological shifts in manufacturing, in particular, by the level of IT development.

C. Davidson & S. Nicholas (2013) describe the educational behavior model of the economically active population and the impact of globalization on these processes. Foreign researchers use a combination of judgment-based, statistical and mathematical methods to estimate the role of each sector in the country's total employment (Nyen Wong & Cheong Tang, 2011; Groen & Kapetanios, 2016). Recruitment needs are determined in accordance with the main development parameters based on a dynamic model of sectoral balance with regard to the planned consolidated balance of labor resources. This approach was described by X. Zhu (2014), along with original assessment of the education impact on the national economic growth.

Judging by relevant publications, Western economics widely uses employment demand functions, based on the relationship between the output volume in any sector of the economy and the volume of the necessary resources (including labor resources) (Athique, 2016; Skousen, 2016). Solution of this problem demands a stable trend in the volume of output and employment. However, in the face of uncertainty on the Russian market, researchers cannot use this opportunity.

The analysis of employee turnover model leads to the following conclusion. The evolution of these models takes place in such a way that the study of numerical characteristics shifted to the study of decision-making process regarding the change of workplace. In addition, the development of employee turnover models provides the possibility to use them for detailed study of the population and labor force movement patterns at the regional level, as well as for a more in-depth study and consideration of its individual components. Y. Zenou (2015) examined a mathematical model of the type of behavior that reflected job search in the labor market. Social communication process and dissemination of information about possible employment is the subject of modeling.

The paper of G. E. Bijwaard, C. Schluter & J. Wahba (2014) presented a mathematical model of migration. The authors proposed a regression model that could be used to assess the probability of immigrants' return to the domestic labor market and timing period of their absence. Some scholars also considered a mathematical model of migration and the impact of migration on the national labor market.

The paper focused on the low-skilled contingent of migrant workers (Didkovskaya, 2014). The study of professional choice and job prestige assessment (Teslenko, 2014; Makarov et al., 2014) is considered in terms of analyzing the behavioral aspects of young people in the labor market. In particular, the study of A.N. Makarov et al. (2014) showed the role of vocational training for sustainable economic development. Ambiguous mutual impact of economic processes and the processes related to vocational training is also presented in modern studies (Pitukhin & Gurtov, 2006).

It should be noted that the vast majority of applied labor market studies in modern Russia are focused on qualification requirements for a given profession, that is, they are related to the order of employers' demand for high-quality vocational education. Recruitment needs of the regional economy both in the quantitative aspect, and in the context of professions and occupations rarely become the research subject.

Aim of the Study

The aim of the study is to justify the methods for finding optimal structure of professional qualification training and determination the occupational skill structure of admission in the vocational training system.

Research questions

The main research questions were as follows:

What are the main components of the model of professional-qualification structure of admission to educational institutions? What are the features of modern approaches to forecasting labor demand in different countries?

Methods

The proposed methodology was based on the following basic ideas:

1. Since forecasting of regional staffing needs is the main link in the whole interaction mechanism of regional labor markets and vocational training, and the benchmark of forecast development implies its use to form the annual regional order for training in the field of primary, secondary and higher vocational education, the method of labor market analysis suggests that prediction of professional staffing needs of the economy should be based on professions and specialties, not on sectors.

2. The analysis of existing approaches to the development of medium-term staffing forecasts showed that none of the methods used could be considered satisfactory in terms of implementation of forecasting purposes. A complementary approach is required, including various research and forecasting methods as regards labor market.

3. Additional research methods may include a secondary analysis of statistical data and identification of employment trends; the analysis of programs and projects related to social and economic development of the region; the analysis of investment plans and programs elaborated for the real sector of regional economy; the analysis of demographic statistics. With regard to the testing experience, the need to use additional methods is determined by specific background of the employers' subjective focus on development prospects.

4. The primary method of gathering information should focus on direct surveys of employers in the region, as both current and future employment structures have significant differences even at homogeneous enterprises. With this approach, one can partially neutralize substitutability of professionals because personnel services are well aware of the particular employment structure specifics. The proposed method differs from the methodology developed, for example, by the Finnish National Board of Education.

5. Forecasting total staffing needs as regards skilled workers, specialists with secondary and higher vocational education, i.e. training at all levels is fundamentally important for the formation of a regional order for vocational education. This differs the original methodology from the one implemented in Petrozavodsk State University.

Structure of the proposed methodology

The original methodology presented in this article is based on the system-dynamic model. The optimization criterion of this model is considered as the absolute value of the integral imbalance in the labor market of a particular region for all consolidated groups of specialties for a certain reporting period (10-15 years). The balance between the economic need for professional staff and demand in the regional labor market is affected by many socio-economic factors.

The main "levers" of the model (model variables) are presented by a professional-qualification structure of admission to educational institutions with regard to different levels (primary, secondary and higher) of vocational education (admission quotas). The proposed model considers three main groups of processes: formation of labor resources (birth rate, distribution of students between the complete and secondary education, the distribution of students between the specialties of primary, secondary and higher education), labor force functioning (professional retraining, labor migration, economic demand for the labor force), outflow of the labor force (retirement, disability, death).

The authors suggested a general algorithm for determining the occupational skill structure in the professional training system. It consists in a number of specific interrelated steps that are required to solve this problem. These interrelated steps form a network diagram (Figure 1).

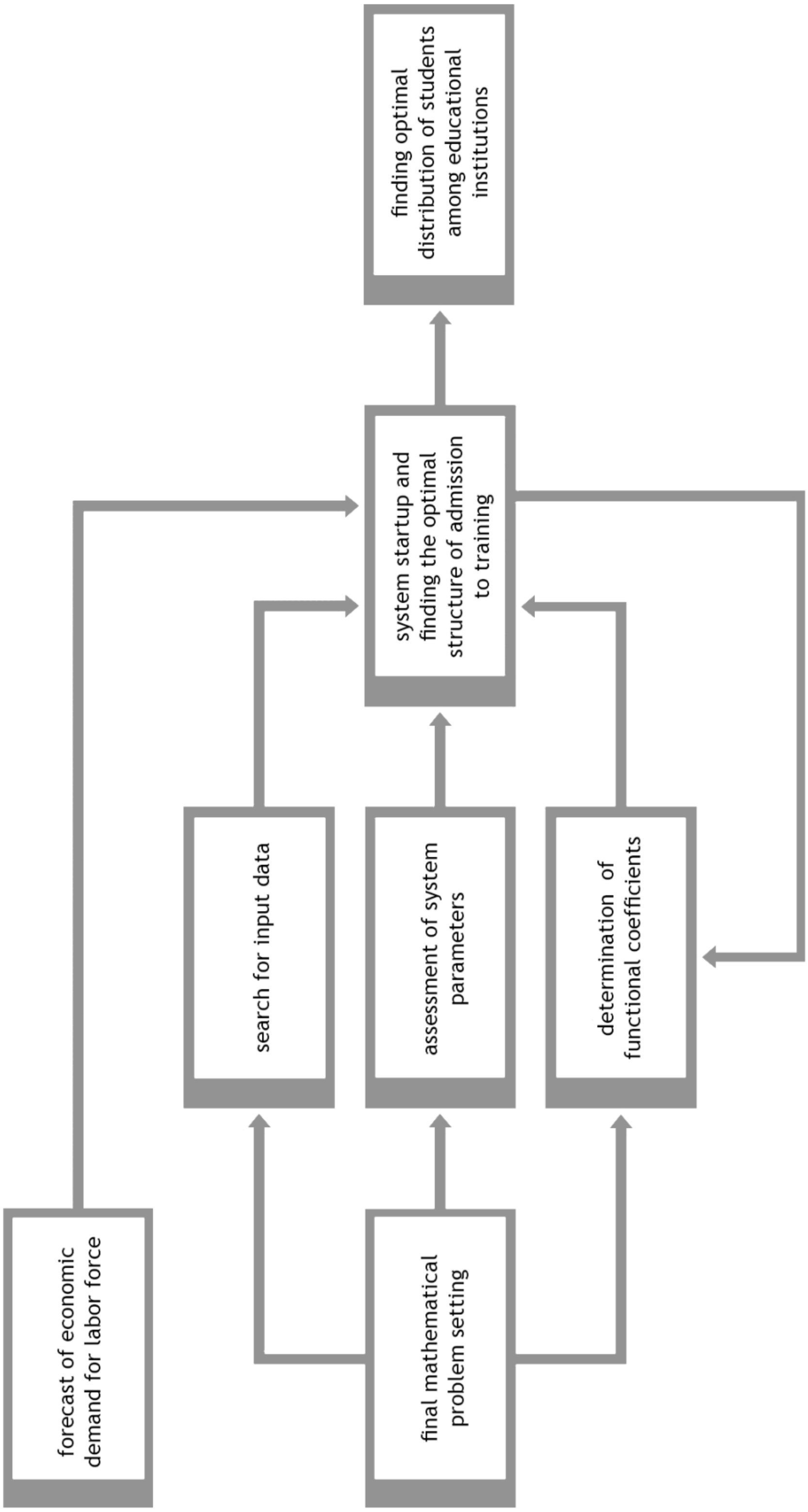

Figure 1. Network diagram of steps required to determine the optimal admission structure

Data, Analysis, and Results

Forecast of economic demand for labor force

This stage aims at finding the set of values $\hat{P}_{i_k}(1),\ldots,\hat{P}_{i_k}(s+\tau_3^e)$, $i=\overline{1,N}$, $k=\overline{1,K}$. Here, $\hat{P}_{i_k}(1),\ldots,\hat{P}_{i_k}(s+\tau_3^e)$ projected values of economic demand for labor force in the i_k - group of specialties up to $s+\tau_3^e$ - year.

This dataset can be obtained by a researcher using a mathematical model, or determined by relevant departments. The second option seems preferable if these agencies have information that allows making a more accurate forecast. This information may include:

- data related to the personnel policy of large and medium-sized enterprises, which have an impact on the labor market situation in the region, or may become key factors in the economy or in the development of cities, towns or small towns in rural areas;

- regional development plans for a number of years, involving, in particular, the need for a certain amount of personnel, presenting certain professions and so on.

Finally, in order to complete this phase, one needs to fill NK in the following tables by each i_k group of specialties (Table 1).

Table 1. Initial data on the structure of demand for labor resources

Indicator	$\hat{P}_{i_k}(1)$	$\hat{P}_{i_k}(2)$	. . .	$\hat{P}_{i_k}(s+\tau_3^e)$
Value				

Mathematical problem setting

The purpose of this stage is to provide final formalization of the problem up to a certain set of unknown parameters. At this stage, one needs to define a specific type of each function involved in the dynamic operation of the system, perhaps up to a certain set of parameters. In addition, it is also necessary to assign values of all constants involved in the system. Thus, by the end of this stage the dynamical system will be finally formed.

The list of constants that need to be specified is as follows:

R – number of secondary education levels. This constant is specified unequivocally, $R=2$ (lower secondary education and upper secondary education);

N – number of groups of specialties;

K – number of professional education levels. This constant is also specified unequivocally, $K=3$ (initial vocational education, secondary vocational education and higher professional education);

H – number of other regions of the Russian Federation;

τ_k^e – number of study years at the k-level of professional education, $k=\overline{1,K}$. This constant is specified unequivocally, namely: $\tau_1^e=2$ (study period of the initial vocational education), $\tau_1^e=4$ (study period of the secondary vocational education), $\tau_1^e=5$ (study period of the higher professional education);

s – duration of forecasting the occupational skill structure of students. This constant is determined by the researcher.

The following functions need to be specified:

$g_{i_k}(t)=\upsilon(D_{i_k}([t]+1-\tau_k^e))$ – graduation intensity of the new specialists referring to the i_k group of specialties in the moment t;

$x_{i_k j_l}(t)=\varphi(W_{i_k}(t),W_{j_l}(t),X_{i_k}(t),P_{i_k}(t),V_{i_k j_l}(t))$ – re-training intensity of workers referring to the i_k group of specialties to the j_l group of specialties in the moment t;

$y_{i_k}(t)=\gamma(W_{i_k}(t),\tilde{W}_{i_k}^1(t),\ldots,\tilde{W}_{i_k}^H(t),X_{i_k}(t),P_{i_k}(t),U(t))$ – migration intensity of workers referring to the i_k group of specialties in the studied region to other regions in the moment t;

$\tilde{y}_{i_k}(t)=\tilde{\gamma}(W_{i_k}(t),\tilde{W}_{i_k}^1(t),\ldots,\tilde{W}_{i_k}^H(t),\tilde{X}_{i_k}^1(t),\ldots,\tilde{X}_{i_k}^H(t),U(t))$ – migration intensity of workers referring to i_k group of specialties from other regions to the studied region in the moment t;

$z_{i_k}(t)=\lambda(Z_{i_k}([t]+1))$ – natural outflow intensity of workers referring to i_k group of specialties in the moment t;

$\frac{\partial W_{i_k}(t)}{\partial t}=\omega\left(X_{i_k}(t),P_{i_k}(t),\frac{\partial X_{i_k}(t)}{\partial t},W_{i_k}(t)\right)$ – salary change rate in the i_k group of specialties in the moment t.

The economic essence of these functions, relevant requirements and their possible expression are described in A. Athique's (2016) study.

Search for input data

This stage implies finding a set of data required for the operation of a dynamic system during $s+\tau_3^e$ years. It can be briefly express it as follows.

$B_1(1),\hat{B}_1(2),\ldots,\hat{B}_1(s+2)$ – instantaneous value of the total quantity of 11th graders and predicted values of the total quantity of 11th graders up to $(s+2)$-year.

$B(1), \hat{B}(2), ..., \hat{B}(s)$ – instantaneous value of the total quantity of 9th graders and predicted values of the total quantity of 9th graders up to s - year.

Therefore, one is to fill in the following table (Table 2).

Table 2. Input data related to the structure of schoolchildren

Indicator	$B_1(1)$	$\hat{B}_1(2)$	. . .	$\hat{B}_1(s)$	$\hat{B}_1(s+1)$	$\hat{B}_1(s+2)$
Value						
Indicator	$B(1)$	$\hat{B}(2)$		$\hat{B}(s)$		
Value						

$D_{i_k}(1-\tau_k^e), ..., D_{i_k}(0)$ – known quantity of applicants admitted to each i_k - group of specialties during the past years; 5 years for the higher professional education, 4 years for the secondary vocational education, 2 years for the elementary vocational education, $i = \overline{1, N}$, $k = \overline{1, K}$.

Therefore, one is to fill in N of the following tables (Table 3) related to each i – group of specialties.

Table 3. Input data related to the structure of students getting vocational education

Indicator	$D_{i_1}(-4)$	$D_{i_1}(-3)$	$D_{i_1}(-2)$	$D_{i_1}(-1)$	$D_{i_1}(0)$
Value					
Indicator		$D_{i_2}(-3)$	$D_{i_2}(-2)$	$D_{i_2}(-1)$	$D_{i_2}(0)$
Value					
Indicator				$D_{i_3}(-1)$	$D_{i_3}(0)$
Value					

$X_{i_k}(0)$ – distribution of workers by groups of specialties by the beginning of the current year.

$\hat{\tilde{X}}_{i_k}^h(1), ..., \hat{\tilde{X}}_{i_k}^h(s+\tau_3^e)$ – predicted values of the number of workers in each i_k group of specialties in each h region up to $s+\tau_3^e$ year, $i = \overline{1, N}$, $k = \overline{1, K}$, $h = \overline{1, H}$.

Therefore, one is to fill in NKH of the following tables – by each i_k group of specialties in each h region (Table 4).

Table 4. Input data related to the labor force structure of other regions

Indicator	$\hat{\tilde{X}}_{i_k}^h(1)$	$\hat{\tilde{X}}_{i_k}^h(2)$	. . .	$\hat{\tilde{X}}_{i_k}^h(s+\tau_3^e)$

Value

$W_{i_k}(0)$ – distribution of wage levels by groups of specialties by the beginning of the current year.

$\hat{\tilde{W}}_{i_k}^h(1),\ldots,\hat{\tilde{W}}_{i_k}^h(s+\tau_3^e)$ – predicted values of wage levels in each i_k group of specialties in each h region up to $s+\tau_3^e$ year, $i=\overline{1,N}$, $k=\overline{1,K}$, $h=\overline{1,H}$.

Therefore, one is to fill in NKH of the following tables by each i_k group of specialties in each h region (Table 5).

Table 5. Input data related to the wage structure in other regions

Indicator	$\hat{\tilde{W}}_{i_k}^h(1)$	$\hat{\tilde{W}}_{i_k}^h(2)$	. . .	$\hat{\tilde{W}}_{i_k}^h(s+\tau_3^e)$
Value				

$V_{i_k j_l}$ – costs related to retraining of workers from each i_k group of specialties to each j_l group of specialties.

U – costs related to migration of workers to other regions or from other regions.

$\hat{Z}_{i_k}(1),\ldots,\hat{Z}_{i_k}(s+\tau_3^e)$ – predicted values of quit workers of each i_k group of specialties up to $s+\tau_3^e$ year, $i=\overline{1,N}$, $k=\overline{1,K}$. The value $\hat{Z}_{i_k}(T)$ includes assessment of a number of retirements and mortality among the working population.

Therefore, one is to fill in NK of the following tables (Table 6) by each i_k group of specialties.

Table 6. Input data related to the natural outflow structure of workers.

Indicator	$\hat{Z}_{i_k}(1)$	$\hat{Z}_{i_k}(2)$	. . .	$\hat{Z}_{i_k}(s+\tau_3^e)$
Value				

The values of relevant indicators for the past periods can be obtained from statistics and predictive values of the indicators can be calculated using some mathematical models based on the values obtained during the previous periods, for example, through econometric models, time series models etc.

Assessment of system parameters

The purpose of this stage is to estimate the parameters that characterize the behavior of various functions that form the intensity of labor force flows. This operation, generally speaking, cannot be described unequivocally because the set of system parameters may vary considerably depending on the type of functions used in the system.

Preparatory step

Constructing set of system parameters to be assessed $\theta_1,...,\theta_q,...,\theta_Q$ and defining for each parameter θ_q its set of values Ω_q, $q=\overline{1,Q}$.

Division of this set of parameters into the group $\theta_1,...,\theta_{Q_1}$, which can be assessed beyond the dynamic system and the group $\theta_{Q_1+1},...,\theta_Q$, which cannot be assessed beyond the dynamic system.

Expert assessment of parameters $\theta_1,...,\theta_{Q_1}$ by using econometric modeling or any other method.

Assigning the constant C, indicating the number of years for studying compliance of a dynamic system and real situation in the region in order to assess the remaining parameters $\theta_{Q_1+1},...,\theta_Q$.

Then we proceed to assessing the parameters $\theta_{Q_1+1},...,\theta_Q$.

Search for input data for assessing the parameters $\theta_{Q_1+1},...,\theta_Q$

In order to provide functioning of the dynamic system during C years, the following dataset is required:

$B_1(1-C),...,B_1(0),B_1(1),\hat{B}_1(2)$ – historical data indicating the number of 11th graders for C past years and the predicted number of 11th graders in two subsequent years.

$B(1-C),...,B(0)$ – historical data indicating the total number of 9th graders for C past years.

Hence, one is to fill in the following table (Table 7)

Table 7. Input data related to the structure of schoolchildren.

Indicator	$B_1(1-C)$	$B_1(2-C)$	...	$B_1(0)$	$B_1(1)$	$\hat{B}_1(2)$
Value						
Indicator	$B(1-C)$	$B(2-C)$	...	$B(0)$		
Value						

$D_{i_k}(1-C-\tau_k^e),...,D_{i_k}(-\tau_k^e)$ - historical values indicating a number of students admitted to i_k group of specialties; during $C+5$ past years - for the higher professional education, during $C+4$ past years - for the secondary vocational education, during $C+2$ past years - for the elementary vocational education, $i=\overline{1,N}$, $k=\overline{1,K}$.

Thus, one is to fill in N of the following tables (Table 8) by each i group of specialties.

Table 8. Input data related to the structure of students getting vocational education.

Indicator	$D_{i_1}(1-C-5)$	...	$D_{i_1}(-5)$
Value			
Indicator	$D_{i_1}(1-C-4)$	...	$D_{i_2}(-4)$
Value			
Indicator	$D_{i_1}(1-C-2)$	...	$D_{i_3}(-2)$
Value			

$X_{i_k}(-C)$ – distribution of workers by groups of specialties, by the beginning of the year C years ago, $i=\overline{1,N}$, $k=\overline{1,K}$.

$\tilde{X}_{i_k}^{h}(1-C),\ldots,\tilde{X}_{i_k}^{h}(0)$ – historical values of the number of workers in the i_k group of specialties in h-region during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$, $h=\overline{1,H}$.

Thus, one is to fill in NKH of the following tables – by each i_k group of specialties in each h region (Table 9).

Table 9. Input data related to the structure of labor resources from other regions.

Indicator	$\tilde{X}_{i_k}^{h}(1-C)$	...	$\tilde{X}_{i_k}^{h}(0)$
Value			

$P_{i_k}(1-C),\ldots,P_{i_k}(0)$ – assessment of the past values of economic demand for the labor force in the i_k group of specialties during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$.

Thus, one is to fill in NK of the following tables – by each i_k group of specialties (Table 10).

Table 10. Input data related to the structure of economic demand for the labor force.

Indicator	$P_{i_k}(1-C)$	...	$P_{i_k}(0)$
Value			

$W_{i_k}(-C)$ – distribution of wage level by groups of specialties at the beginning of the year C years ago, $i=\overline{1,N}$, $k=\overline{1,K}$.

$\tilde{W}_{i_k}^{h}(1-C),\ldots,\tilde{W}_{i_k}^{h}(0)$ – historical values of wage level in the i_k groups of specialties in the h-region during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$, $h=\overline{1,H}$.

Thus, one is to fill in NKH of the following tables – by each i_k groups of specialties in each h region related to one of the presented expressions (Table 11).

Table 11. Input data related to wage structure in other regions.

Indicator	$\tilde{W}_{i_k}^h(1-C)$	...	$\tilde{W}_{i_k}^h(0)$
Value			

$V_{i_k j_l}$ − costs related to retraining of workers of each i_k groups of specialties to each j_l group of specialties.

U − costs, related to migration of workers to other regions or from other regions.

$Z_{i_k}(1-C),...,Z_{i_k}(0)$ − historical values indicating the volume of labor force outflow by groups of specialties during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$.

Thus, one is to fill in NK of the following tables (Table 12) by each i_k group of specialties.

Table 12. Input data related to natural outflow structure of workers.

Indicator	$Z_{i_k}(1-C)$	...	$Z_{i_k}(0)$
Value			

Solution of this problem requires a set of historical values that will be used to compare the work of a dynamic system and the real regional situation.

Search for additional data with the view of assessing the parameters $\theta_{Q_1+1},...,\theta_Q$

Let us assume that $X_{i_k}(1-C),...,X_{i_k}(0)$ – historical values indicating the number of workers in the i_k group of specialties during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$.

Thus, one is to fill in NK of the following tables – by each i_k group of specialties (Table 13).

Table 13. Input data related to labor force structure.

Indicator	$X_{i_k}(1-C)$	...	$X_{i_k}(0)$
Value			

The indicator $W_{i_k}(1-C),...,W_{i_k}(0)$ presents the historical values of wage level by the end of the year in the i_k group of specialties during C past years, $i=\overline{1,N}$.

Thus, one is to fill in NK of the following tables – by each i_k group of specialties (Table 14).

Table 14. Input data related to wage structure.

Indicator	$W_{i_k}(1-C)$	...	$W_{i_k}(0)$
Value			

$Y_{i_k}(1-C),...,Y_{i_k}(0)$ – historical values of a number of workers in the i_k group of specialties, who moved from the studied region to other regions during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$.

These data should be entered in the NK of the following tables – by each i_k group of specialties (Table 15).

Table 15. Input data related to the structure of migration to other regions.

Indicator	$Y_{i_k}(1-C)$	...	$Y_{i_k}(0)$
Value			

$\widetilde{Y}_{i_k}(1-C),...,\widetilde{Y}_{i_k}(0)$ – historical values of a number of workers in the i_k group of specialties, who moved to the studied region from other regions during C past years, $i=\overline{1,N}$, $k=\overline{1,K}$.

Thus, one is to fill in NK of the following tables – by each i_k group of specialties related to one of the presented expressions (Table 16).

Table 16. Input data related to the structure of migration to the studied region.

Indicator	$\widetilde{Y}_{i_k}(1-C)$	...	$\widetilde{Y}_{i_k}(0)$
Value			

Determining functional coefficients in the assessment of parameters $\theta_{Q_1+1},...,\theta_Q$

This stage implies determination of weight coefficients in the assessment of parameters $\theta_{Q_1+1},...,\theta_Q$ pursuant to research requirements, namely:

λ_1 - coefficient determining weight function of labor resource;

λ_2 - coefficient determining weight function of wages,

λ_3 - coefficient determining weight function of migration.

Solving the task aimed at assessment of parameters $\theta_{Q_1+1},\ldots,\theta_Q$

Mathematically, the problem of fitting the work of a dynamic system to the real situation in the region could be solved by minimizing the sum of squared deviations of model values (obtained in a dynamic system) from the real values – using a set of indicators with corresponding weight coefficients.

This set of indicators, generally speaking, is not strictly defined. For a given set of parameters $\theta_{Q_1+1},\ldots,\theta_Q$ one should select specific set of indicators, in order to avoid complex calculations. In the most general case, we suggest using the following indicators:

$X_{i_k}(T)$ – number of workers in the i_k group of specialties in the year T, $i=\overline{1,N}$, $k=\overline{1,K}$.

$W_{i_k}(T)$ – wage level in the i_k group of specialties in the year T, $i=\overline{1,N}$, $k=\overline{1,K}$.

$Y_{i_k}(T)$ – number of workers in the i_k group of specialties, who moved from the studied region to other regions in the year T, $i=\overline{1,N}$, $k=\overline{1,K}$.

$\widetilde{Y}_{i_k}(T)$ – number of workers in the i_k group of specialties, who moved from other regions to thee studied region in the year T, $i=\overline{1,N}$, $k=\overline{1,K}$.

The above indicators are reflected in a dynamic system by the following values:

$\hat{X}_{i_k}(t=T)$ – the assessed number of workers in the i_k group of specialties at the moment $t=T$, $i=\overline{1,N}$, $k=\overline{1,K}$.

$\hat{W}_{i_k}(t=T)$ – the assessed wage level in the i_k group of specialties at the moment $t=T$, $i=\overline{1,N}$, $k=\overline{1,K}$.

$\hat{Y}_{i_k}(T)=\int\limits_{T-1}^{T} y_{i_k}(t)dt$ – the assessed number of workers in the i_k group of specialties, who moved from the studied region to other regions in the year T, $i=\overline{1,N}$, $k=\overline{1,K}$.

$\hat{\widetilde{Y}}_{i_k}(T)=\int\limits_{T-1}^{T} \widetilde{y}_{i_k}(t)dt$ – the assessed number of workers in the i_k group of specialties, who moved from other regions to the studied region in the year T, $i=\overline{1,N}$, $k=\overline{1,K}$.

In the following, one is to solve the following optimization problem:

$$F = \sum_{i,k}\left[\lambda_1 \sum_{T=1-C}^{0}(X_{i_k}(T) - \hat{X}_{i_k}(T))^2 + \lambda_2 \sum_{T=1-C}^{0}(W_{i_k}(T) - \hat{W}_{i_k}(T))^2 + \right.$$

$$\left. + \lambda_3 \sum_{T=1-C}^{0}((Y_{i_k}(T) - \hat{Y}_{i_k}(T))^2 + (\tilde{Y}_{i_k}(T) - \hat{\tilde{Y}}_{i_k}(T))^2)\right] \to \min_{\theta_{Q_1+1},\dots,\theta_Q}$$

$$\frac{\partial X_{i_k}(t)}{\partial t} = g_{i_k}(t) + \sum_{j,l} x_{j_l i_k}(t) - \sum_{j,l} x_{i_k j_l}(t) + \tilde{y}_{i_k}(t) - y_{i_k}(t) - z_{i_k}(t)$$

$$\frac{\partial W_{i_k}(t)}{\partial t} = \omega\left(X_{i_k}(t), P_{i_k}(t), \frac{\partial X_{i_k}(t)}{\partial t}, W_{i_k}(t)\right)$$

$$\theta_q \in \Omega_q,\ q = \overline{Q_1+1, Q}$$

Having solved the above problem, we obtain assessments of parameters $\theta_{Q_1+1},\dots,\theta_Q$, providing providing the highest compliance of the dynamic system with the real situation in the region.

Defining functional coefficients

The purpose of this step is to provide definition of functional coefficients in accordance with the researcher's requirements, namely:

α − coefficient that determines the impact of the lack of labor resources on the functional;

β − coefficient that determines the impact of excessive labor resources on the functional;

μ_{i_k} − coefficient that determines weight of i_k group in the functional.

Finding the optimal occupational skill structure of admission to training

In order to let the dynamic system find the optimal occupational skill structure of students, one needs to monitor its work during the entire formation period of professional education needs s.

Then, during the minimum period of professional education – the elementary vocational education - $\tau_3^e = 2$.

At that, graduation of new specialists will not be interrupted before the dynamic system shuts down, and at the same time, all flows of graduates which values need to be found, and which are designed to optimize system performance, will have relevant impact on it. Thus, the required period of the dynamic system makes $s + \tau_3^e$ years.

The task of finding balance between the available labor force and the staffing needs is mathematically represented as follows: we are launching a dynamic workforce movement system for the period $s + \tau_3^e$ years, during this period we compute "penalties" in a certain amount α_1 for each excessive worker of i_k specialty with weight coefficient μ_{i_k} and in a certain amount α_2 for each lacking worker of i_k specialty with weight coefficient μ_{i_k}. Then, "penalties" accumulated during the period $s+\tau_3^e$ in each specialty are subject to minimization by means of parameters $D_{i_k}(1),...,D_{i_k}(s)$, in other words, through the admission structure to the educational establishments during the period s. At that, we set the system mode: the rate of change in the number of employees in each i_k group of specialties as the difference between the intensity of the incoming flow of labor resources (graduates, retraining, migration) and the intensity of the outgoing flows of labor force (retraining, migration, natural outflow), as well as the rate of change in wage levels in each i_k group of specialties. In addition, we set limits on the parameters $D_{i_k}(1),...,D_{i_k}(s)$.

The total amount of "penalties" for the lack or excess of workers in a certain specialty reflects the mismatch of available labor force and relevant staffing needs during the period of the system operation $s+\tau_3^e$.

Minimization of the above "penalties" provides the best possible matching of available labor resources and staffing needs of the economy that can be achieved by changing only the structure of admission to vocational schools.

Then one is to solve the following optimization problem:

$$F=\sum_{i,k}\int_0^{s+\tau_3^e}[\alpha\mu_{i_k}(P_{i_k}(t)-X_{i_k}(t))\beta(P_{i_k}(t)-X_{i_k}(t))+\beta\mu_{i_k}(X_{i_k}(t)-P_{i_k}(t))\beta(X_{i_k}(t)-P_{i_k}(t))]dt\rightarrow\min_{D_{i_k}(1),...,D_{i_k}(s)}$$

$$\frac{\partial X_{i_k}(t)}{\partial t}=g_{i_k}(t)+\sum_{j,l}x_{j_l i_k}(t)-\sum_{j,l}x_{i_k j_l}(t)+\tilde{y}_{i_k}(t)-y_{i_k}(t)-z_{i_k}(t)$$

$$\frac{\partial W_{i_k}(t)}{\partial t}=\omega\left(X_{i_k}(t),P_{i_k}(t),\frac{\partial X_{i_k}(t)}{\partial t},W_{i_k}(t)\right)$$

$$\sum_{i,k}D_{i_k}(T)=\sum_r B_r(T)$$

$$\sum_i D_{i_1}(T)\le B_1(T)$$

Here F − functional of the problem, defining the amount of penalties during the period $s+\tau_3^e$,

$\frac{\partial X_{i_k}(t)}{\partial t}$ − the rate of change in the number of workers in the i_k group of specialties, as a function of the intensities of labor force flows included into this group and the intensities of labor force specialties emanating from this group,

$\frac{\partial W_{i_k}(t)}{\partial t}$ − rate of change in wage level in the i_k group of specialties.

$\frac{\partial X_{i_k}(t)}{\partial t}$ and $\frac{\partial W_{i_k}(t)}{\partial t}$ set the operation mode of the dynamic system.

$\sum_{i,k} D_{i_k}(T) = \sum_{r} B_r(T)$ and $\sum_{i} D_{i_1}(T) \le B_1(T)$ - restrictions on the structure of admission to professional schools, determined by a certain number of high school graduates with incomplete and complete secondary education.

Having solved the above problem, we obtain the optimal (for this criterion function F) occupational skill structure of admission for the period s years – $D_{i_k}(1),...,D_{i_k}(s)$.

Finding the optimal distribution of students by educational institutions

The described steps, as mentioned above, form a network schedule. At the time zero, the stages "Forecast of economic demand for labor force” and "Final mathematical problem setting” start simultaneously; they can be implemented independently of each other. Completing the "Final mathematical problem setting” opens up a new horizon of available work, namely "Search for input data", "Assessment of system parameters” and “Definition of functional coefficients". Each of these operations may be performed independently as well. Only upon completion of the above works, it is possible to proceed to the next, central stage – “System launch and search for optimal admission structure". As a result, a researcher decides either to revise the task that is to re-do the stage “Definition of functional coefficients”, or moves to the final stage – “Finding the optimal distribution of students by educational institutions”.

Order of execution on stages

This is the final stage, which allows transforming the overall occupational skill structure of students into concrete admission volumes by specific specialties related to specific educational institutions, i.e., the numbers that can be used in practice. This task involves potential assessment of educational institutions in terms of training specialists with regard to certain occupational skill structure, namely the availability of places, material and technical resources (premises, equipment), human resource capacity, legal framework, etc.; assessment of the quality of knowledge obtained in a particular school and in a particular specialty, identification of optimal criteria of occupational distribution of students and its improvement.

Discussion and Conclusion

Both domestic and foreign science and practice accumulated certain experience in methodological and methodical maintenance forecasting the demand for specialists. In the US, development of human resource forecasts is provided by the Bureau of Labor Statistics (BLS Handbook of Methods, 1997). Mid-term forecasts (up to 10-15 years) are specified every two years and are part of the medium-term program aimed at managing economic growth and employment. The US Bureau of Labor Statistics conducts employment forecasting within the framework of six interrelated phases, which envisage six interrelated elements of the model (Figure 1). The results of each previous stage are of key importance for each subsequent stage. Forecast methodology is given in the BLS Handbook of Methods published by US Bureau of Labor Statistics.

According to the authors of this method, any decisions taken on the labor market should correspond to the real situation in the economy. In this regard, the effectiveness of any decisions and activities may be assessed only after a certain period. That is why labor market forecasts need to focus on the analysis of the total income and expenditure in the economy, and then one needs to find an optimal balance between labor supply and demand, providing GDP increase.

In France, labor force forecasting is carried according to the “five-year plan” principle (Upward & Wakelin, 2002). The evolution of methodological approaches used by the Commission on the labor force in this country demands specific attention. In 1960s, only extrapolation techniques were used along with fragmented application of scenario options in separate, especially dynamic industries. In 1970s, the material and financial model was largely used. At the end of the XX century, this model was replaced by a dynamic econometric model of medium-term economic development, presenting an incident sequence of annual interrelated balances (involving 11 economic sectors). Today, France is actively reviewing the labor force concept in its traditional application.

Researchers believe that current employment structures are characterized by substantial variations depending on different variables that characterize the activities of enterprises. For example, the structure of employment (even in the case of similar products) is very different in the enterprises that are similar in technical terms.

Petrozavodsk State University also has significant experience in the development of medium-term forecasts of recruitment needs of territories. A team of researchers led by Professor V. Gurtov carried out a scientifically grounded analysis of labor market needs and calculated the need for trained specialists with higher education for 18 economic sectors in the Republic of Karelia (Kosorukov, 2015; Athique, 2016; Gurtov, Garifullina & Sigova, 2016). However, the method proposed by V. Gurtov did not actually involve assessment of technological mode.

In contrast to the methods proposed by V. Gurtov, the original method involves assessment technological mode, and as a result, labor productivity with regard to a number of factors: the maximum available technological power unit level; distribution of facilities by technological level; gross output intensity per unit of power with a given technological level.

To sum up, this paper propose a new approach to assessing the economic demand for the new specialists of a particular specialty. The original approach has two key features. Firstly, the described model has a high degree of approximation to the real processes that occur in the labor market. Secondly, mathematical modeling of these processes is characterized by a high degree of complexity. Without high-quality intensity assessment of the above flows and parameters of the dynamic system, the proposed model will not be really close to the real processes.

Furthermore, it should be noted that the described approach is highly flexible, namely, the model has several "set levels"

The first level - the very essence of the model – presents a dynamic system with the "overflow" of labor resources, the optimization problem aimed at minimizing imbalance in the labor force needs and the expected labor force without specifying mathematical functions that define the system operation mode. The second level implies setting of general mathematical functions of the model up to a certain set of parameters. The third level implies definition of the identified set of system parameters.

The researcher has the possibility to edit each of these levels by changing the structure of the system, adding new elements, changing the system operation mode by adjusting the general expression of the functions, as well as by adjusting the values of system parameters. Thus, there are many options for implementing this approach.

Implications and Recommendations

This article was prepared within the research project "The economic aspects of improving the mechanism of vocational training development of human resources in the innovation economy" performed by G. Plekhanov Russian Economic University within the framework of the state order issued by the Ministry of Education and Science of the Russian Federation.

On the basis of foreign studies we offered universal approaches to provide balance in the regional labor market, and considered the need for concerted action of regional authorities, educational and manufacturing companies in the region.

The submissions may be useful in future studies on forecasting labor demand and socio-economic development.

Disclosure statement

No potential conflict of interest was reported by the authors.

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