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Methods for Evaluation of the Region's Needs for Human Resources based on Statistics and Patent Landscapes[1]

Implementation of a new technological platform in Russia requires providing promising areas of professional qualification with human resources. Post-pandemic structural economic transformation has accelerated changes in the labour market and highlighted the need to develop new approaches and forecasting methods with the priorities of regional technological development. The study presents a methodology to reveal the regional demand for staffing based on the analysis of the factors affecting staff demands using structured and unstructured datasets. The study is focused on forecasting the region's needs for human resources based on data mining and patent landscapes. That forecasting should consider the economic focus of a region as well as its location, investment and R&D development programme, labour market specificity. The advantage of the proposed methodology is obtaining reasonable estimates of the region's needs for human resources with data mining and patent landscaping methods in conditions of limited official statistical data. Our database includes more than 25 million records: full-text collections of Russian and foreign patents, research papers, statistical indicators, etc. As a result, we identified promising training areas attractive for qualified personnel in the Vologda region corresponding with the priorities of regional technological development. The future development of this research is the improvement of the methodology for quantitative assessment of the regional need for professionals in particular industries. The obtained results can be useful to government bodies and research centres for the development of regional strategies.

Keywords: regional labour market, post-pandemic structural economic transformation, human resources, data mining, patent landscaping, artificial intelligence

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Оценка потребности региона в человеческих ресурсах на основе анализа статистических данных и патентных ландшафтов

Переход России на новую технологическую платформу актуализирует проблему кадрового обеспечения по перспективным направлениям квалификации. Структурная трансформация экономики после пандемии ускорила изменения на рынке труда, выявив необходимость разработки новых методов прогнозирования с учетом приоритетов регионального технологического развития. Целью данного исследования является разработка новых подходов, основывающихся на структурированных и неструктурированных базах данных, для определения системы факторов формирования потребности в кадровом обеспечении. Потребности региона в человеческих ресурсах были спрогнозированы с использованием методик интеллектуального анализа данных и патентных ландшафтов. Такое прогнозирование учитывает экономическую направленность региона, а также его географическое положение, программу развития инвестиций и НИОКР, специфику рынка труда. Преимуществом предлагаемой методики является получение обоснованных оценок потребности региона в человеческих ресурсах методами интеллектуального анализа данных и патентных ландшафтов в условиях недостатка официальных статистических данных. База исследования включает более 25 миллионов записей: полнотекстовые коллекции российских и зарубежных патентов, научные работы, статистические показатели и т. д. Анализ ситуации в Вологодской области выявил перспективные направления подготовки, привлекательные для квалифицированных кадров и соответствующие приоритетам регионального технологического развития. В дальнейшем планируется совершенствование методики количественной оценки региональной потребности в специалистах отдельных отраслей. Полученные результаты могут быть использованы государственными органами и исследовательскими центрами при разработке региональных стратегий.

Ключевые слова: региональный рынок труда, структурная трансформация экономики в период после пандемии, человеческие ресурсы, интеллектуальный анализ данных, патентные ландшафты, искусственный интеллект

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Introduction

Since Russia set the current course for technological breakthrough, staffing policy became a significant influence on the trajectories of technological development. Therefore, provision of the Russian economy with human resources, meeting the goals of state research and technological development, is an urgent problem that should be solved as soon as possible (Fedotov et al., 2017). At the same time, regional and municipal authorities are in charge of forecasting a local demand for human resources (Zayko, 2018). We have analysed how the Ministry of Economic Development forecasts the demand for human resources in Russia. We revealed that obtaining an adequate forecast is a severe problem because of great unevenness of spatial development; besides, the presented indicators for 85 regions do not coincide with macroeconomic-level indicators. If earlier the Ministry of Economic Development used to collect and process forecasts at the regional level, now this functionality has been completely lost. It should be admitted that the state forecast presents only an averaged figure, which is entirely insufficient to understand the real state of the provision of staff in a spatial context.

In February 2020, the joint extended meeting of the State Council Presidium and the Presidential

Council on Science and Education of the Russian Federation was held. It was focused on the compliance of the secondary vocational and higher education system with the requirements of the economy, and the expectations of the state and society. The central topics of the meeting were issues of increasing the role of regions in training personnel for the economy and society. The President noted that «universities work for the regions, teachers and students live there» and agreed with the proposal to allow the regions to directly finance the development programmes of local universities and their infrastructure, regardless of departmental subordination if resources are available. The President also drew attention to the experience of Cherepovets in creating an effective system for training modern personnel in close cooperation with business. Students of the local Chemical-Engineering College not only receive scholarships from the future employers during their studies, but from the second year of study, they also conduct fieldwork. In his speech, Vladimir Putin emphasised that it is necessary «to make modern educational standards, lists of majors and areas of study more flexible, and also to allow universities, taking into account the needs of students and regions, to form training profiles independently.» At the same time, the areas of personnel training play an essential role in ensuring the technological development of a country. The primary feature of a new step in the development of the economy, which is called the «economy of knowledge», is the importance of knowledge as a factor of production and its impact on skills, learning, organisation and innovation (Houghton, Sheehan, 2000).

The regional-level staffing problem is in the focus of plenty of research now. The region personnel potential, in many respects, determines the success of its development and place in the social division of labour. For example, the article of Denisova (2014) highlights the problem of personnel shortage for regional development on a new technological basis, which requires highly qualified staff.

The existing division of labour, specialisation of production, a specific demographic situation, national characteristics and traditions determine the specificity of a particular region's personnel potential. Akperov and Bryukhanova (2014) proposed an approach, based on the index method known in statistics, for assessing the development of the personnel landscape of a region and its municipalities. Another paper (Kurakova, Zinov, Kotsyubinskiy, 2014) considers various models of a rapid response system to staffing problems in promising research and technology fields.

High mobility of the population, the presence of new challenges and threats in modern society, changing priorities in the prestige and importance of professions require constant improvement of the methodology to deal with the problem of forecasting the regional staffing. In the paper (Filimonenko, Vasilyeva, Vcherashnij, 2017), it is noted that the existing methods for assessing the staffing needs at the regional level do not fully consider systemic changes, which reduce their effectiveness and the quality of the forecasts. Several articles suggest various directions for improving those methods. Zinich and Kuznetsova (2014) proposed a methodology to identify disparities between the directives of long-term target programmes and their staffing. The use of modern foresight turned out to be successful and productive in the forecast of the professions in demand, carried out by the Agency for Strategic Initiatives and the Skolkovo Moscow School of Management. The main result of the study is the Atlas of New Professions (Luksha et al, 2015). On the one hand, in the article (Kuteinitsina, 2016), the author notes that the Russian professional standards and forecasts of competencies describe current or future occupations at the national level — «professions in general», without territorial reference and industry specifics of employment. On the other hand, qualitative medium-term forecasts of the required competencies should be built at the regional level, considering the region's economic specialisation, as well as the specificity of the sectoral distribution of employment.

Attracted investments in industries and projects significantly influence a region's development. At the same time, investments form a request for a certain number of professionals for the additional jobs created in a region. Thus, the consideration of investment programmes and projects is essential for the analysis of local staffing. In the absence of such staff, the need for them will be satisfied not only at the expense of migrant workers but also with training in new specialties on the ground, which corresponds to the fields of the socio-economic and scientific-technical policy. Therefore, in this study, we propose considering staffing in the fields relevant for investment projects and programmes in a region.

The primary goal of the study is to develop new methods and approaches to determine the features affecting the demand for staffing, considering the priority fields of regional research and development (R&D). The following problems have been set to reach the research goal:

1) determining the strategic activities of a region, taking into account the national and region-

al-level objectives and building a patent landscape based on the collections of full-text documents of the FIPS, USPTO, WIPO, EAPO databases in selected strategic fields and forming a list of promising industries in the region;

2) creating a list of promising enterprises in the selected industries, considering their indicators of economic efficiency and participation in local and federal investment programmes and projects;

3) analysing the fields of professional training by universities and identifying promising ones that attract qualified personnel, taking into account the priorities of the technological development of the region.

We chose the Vologda region, an industrially developed area that is part of the Northwestern Federal District, to implement the goal and objectives of this study and to test the proposed methods and approaches.

Methods and Databases

The following data was analysed in this study: Strategy of socio-economic development of the Vologda region[1]; Investment programmes and projects of the Vologda region; patents of the Federal Institute of Industrial Property of the Russian Federation since 1991; foreign patents USPTO, WIPO, EAPO since 2001. The total volume of text data sources amounted to more than 8 million scientific, engineering and regulatory documents. Besides, we used the following statistical bases: results of statistical observations of the Ministry of Education and Science of the Russian Federation (used to identify the main areas of training in regional universities[2]); The Russian Federal State Statistics Service data (Lysov, Sapogova, 2019) (used to determine the structure of employment and income of the population); data from the FIRA[3] information and analytical system, which presents aggregated statistics on all types of economic activity in the context of the constituent entities of the Russian Federation for the analysis of the leading regional players in the most critical areas of science and technology.

The paper presents a methodological research scheme, which includes three main steps (Fig. 1).

At the first step, we identify the types of activities, which are simultaneously mentioned in three primary strategic documents of the federal and local levels[4]. Besides, they should have a high value of the indicator «Industrial Production Index» in comparison with the average level; the enterprises of the selected industries should have high patent activity. Then we build and analyse the patent landscape with the collections of full-text documents from the databases of Russian and foreign patents in the selected strategic fields and form the list of promising industries in the region.

In the second step, as we have several industries selected, we form the list of enterprises and analyse their activities both in terms of indicators of economic efficiency and participation in regional and federal investment programmes and projects.

In the third step, we determine promising areas for training and attracting personnel for the identified enterprises. The third step also includes an analysis of the employment structure, income in the region, and a complete analysis of the areas of professional training by local universities. As the result, we identify promising areas of training and attracting qualified personnel, taking into account the priorities of the regional technological development.

In this study, we used various methods to implement the steps above.

One of the main tasks solved during the generation of the region's promising industry list is the construction of patent landscapes of the related technologies. We use methods of scientific and technical document analysis to build the landscapes. In particular, we apply the full-text information retrieval methods to search scientific and engineering documents, with the syntax and semantic analysis of the queries (Osipov, Smirnov, Tikhomirov, 2010), and methods of full-text document indexing (Sochenkov, Suvorov, 2013) implemented in the TextAppliance system (Ananeva et al., 2016). Based on the basic and applied research results of the Federal Research Center "Computer Science and Control" of RAS, LLC "Technologies for Systems Analysis" has developed the TextAppliance to deal with search and analytical tasks on large-scale text databases. That system helped to carry out loading, indexing,

[1] Resolution of October 17, 2016 No. 920 «On the Strategy of Socio-Economic Development of the Vologda Region for the Period up to 2030 (as amended on June 13, 2018)». Retrieved from: http://base.garant.ru/46309748/.

[2] Retrieved from: https://www.minobrnauki.gov.ru/ru/activity/stat/highed/index.php

[3] Retrieved from: https://fira.ru

[4] Decree of the President of the Russian Federation dated 01.12.2016 No. 642 On the Strategy of Scientific and Technological Development of the Russian Federation. Retrieved from: http://kremlin.ru/acts/bank/41449; On the approval of the Strategy for spatial development until 2025. Retrieved from: http://government.ru/docs/35733/; Resolution of October 17, 2016 No. 920 «On the Strategy of Socio-Economic Development of the Vologda Region for the Period up to 2030 (as amended on June 13, 2018)»]. Retrieved from: http://base.garant.ru/46309748/.

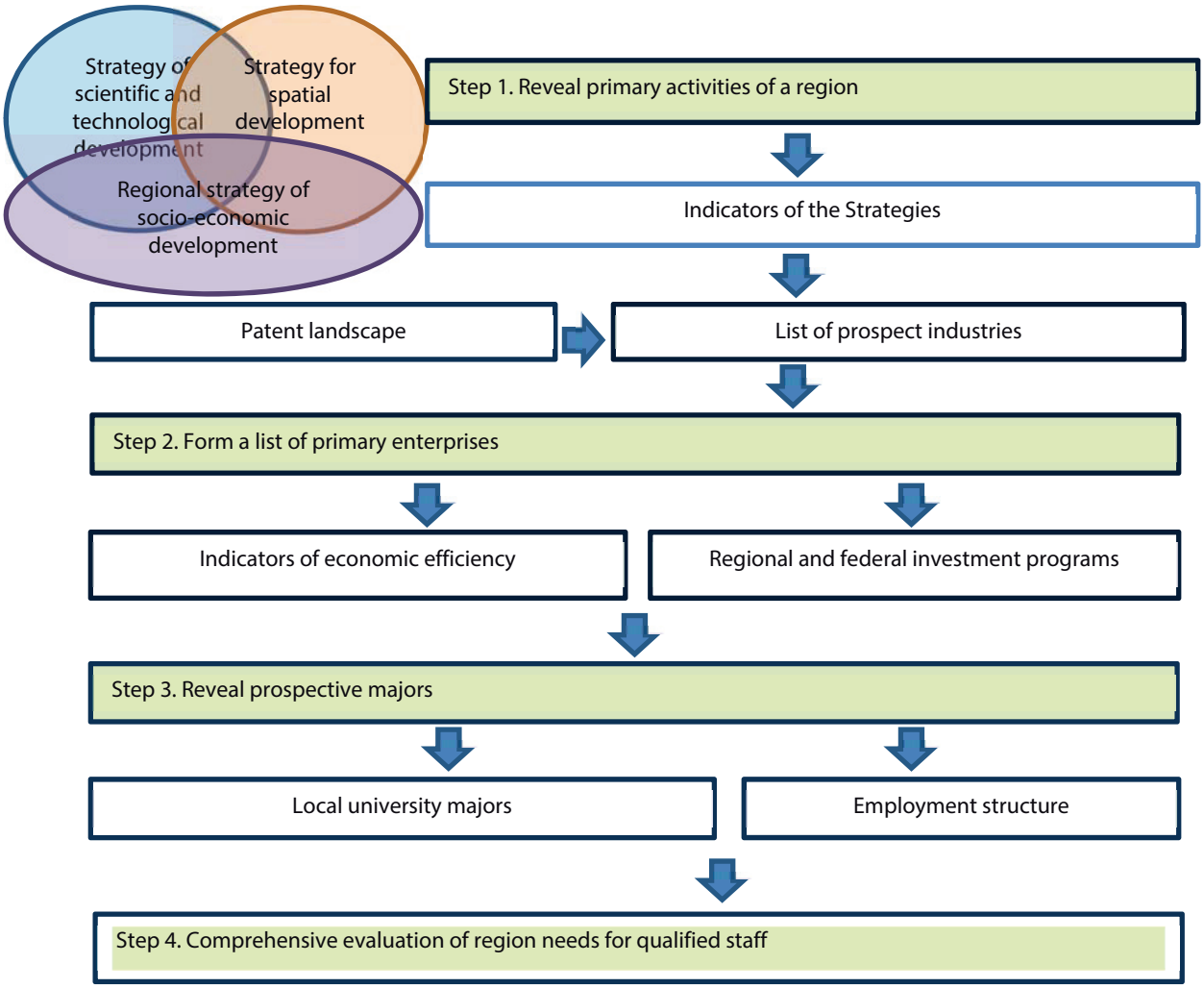


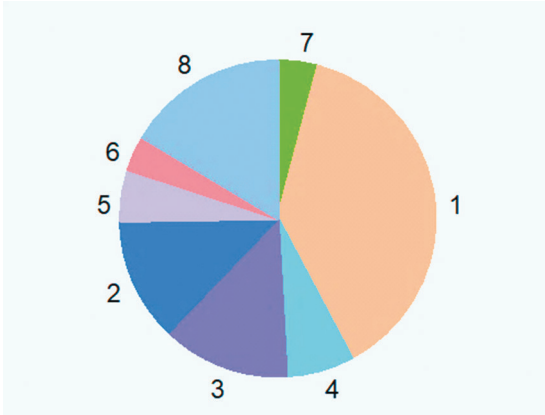
Fig. 1. *The methodological research scheme to reveal the regional demand for staffing*

searching, as well as the construction of aggregated statistics on full-text documents that make up the information base during the study. Besides, we employ the method of identifying technological trajectories (Volkov et al., 2019) to detect documents on individual technologies (Otmakhova et al., 2020a; Otmakhova et al., 2020b), as well as reveal development steps and assess the readiness level of those technologies (TRL). We use methods of financial and economic analysis of the industrial activity, including the study of performance indicators, to identify promising enterprises in the region (Mikhaylov, 2010).

Results and Discussion

There have been positive changes in the economy of the Vologda region over the past ten years. The ratio of the share of all economic activities to the share of economic activities with low added value in 2017 in that region is 1.64, while in other regions of the Russian North-West this indicator has negative values: the Republic of Karelia (–0.72), the Komi Republic (–0.67), the Arkhangelsk region with the Nenets Autonomous District (–0.79), Murmansk region (–3.24) (Leonidova, 2019). Gross regional product (GRP) in 2018 increased by 1.5 times compared to 2014 and amounted to 582.6 billion roubles, and the Vologda region, according to this indicator, took 36th place in the ranking of 85 regions of the Russian Federation. It was revealed that the dominant type of economic activity in the GRP structure is industry, which accounts for 40.0 %. The structure of gross regional product by industry in 2018 is presented in Fig. 2.

In the first step of the study, we revealed the types of activities in the region, which have been simultaneously mentioned as strategic in the three main strategic documents of the state and regional levels, have a high «Industrial Production Index» in comparison with the average Russian indicators and have the enterprises with high patent activity. The growth rates identified as the strategic sectors of the Vologda regional economy (production index) exceeded the average indicators in 2018.



1 – Manufacturing industry (38.1%)
2 – Trade; car and motorcycle service (12.8%)
3 – Logistics and storage (12.7%)
4 – Construction (7.1%)
5 – State control and security; social activities (5.1%)
6 – Agriculture, forestry, hunting, fish farming (4.1%)
7 – Healthcare and welfare (3.6%)
8 – Others (16.5%)

Fig. 2. *Structure of Vologda GRP in 2018*

Table

Description and industrial production index for the strategic activities in Vologda region, 2018

	Industrial production index, 2018, %		Description
	Russia	Vologda region	
Metallurgy	101.7	104.9	The metallurgical industry of the region is one of the largest producers of metal products in Russia, the leading one in the Northwestern Federal District. The largest metallurgical enterprises of the industry in the Vologda Region are the Cherepovets Steel Mill PJSC Severstal, OJSC Severstal-metiz, LLC "Severstal Pipe Profile Plant-Sheksna"
Chemical industry	102.7	108.5	The Vologda region occupies a leading position in the production of chemical products; every sixth ton of mineral fertilisers in the country is produced in this region
Computers and optical industry	103.2	123.4	JSC Vologda Optical and Mechanical Plant (VOMZ) belongs to the optical engineering industry; it has a powerful technological and intellectual background. The plant produces complex optoelectronic, thermal imaging products for special purposes, optoelectronic devices for medical and civil purposes
Food industry	104.9	107.7	The key branch of the food industry is the dairy industry. In 2019, the Vologda region produced half of the total volume of dairy products in the Northwestern Federal District. The three leaders in the industrial processing of milk processing: "Vologda Dairy Plant", JSC «Severnoe Moloko», JSC "Educational and Experimental Dairy Plant of the Vologda State Dairy Farming Academy named after N.V. Vereshchagin"
Forestry	110.6	121.6	The Vologda region is one of the leaders among the constituent entities of Russia in terms of the availability of forest resources. The forests of the Vologda region occupy an area of 11.7 million hectares, which is 81 % of the region's territory

In the structure of industries, the manufacturing industry holds the main share (93.4 %). In the manufacturing industries of the region, the metallurgical production has the largest share.

According to the analysis of the statistics of the Vologda region, it is worth noting that over the past five years, there have been negative trends in the dynamics of changes in the structure of the population. This is due to a decrease in the category of working age people (women aged 16–55 years old and men aged 16–60 years old). Therefore, if the share of that category was 57 % in 2015, then it is 54.5 % at the beginning of 2020. At the same time, there is an increase in the population over the working age: from 24.85 in 2015 up to 26 % in 2020. The revealed structure of the working-age population in Vologda shows why the choice of fields of activity and education majors is crucial; namely, it can smooth out the negative trends.

With the full-text search tools of the TextAppliance system, we searched for patents in specified fields of activity, the patent holders of which are enterprises of the Vologda region. Then the resulting set of the documents was expanded with topically related patents using a similar document search tool. After that, we extracted information about placeholders of these patents to reveal competitors. To build the diagrams, the ag-

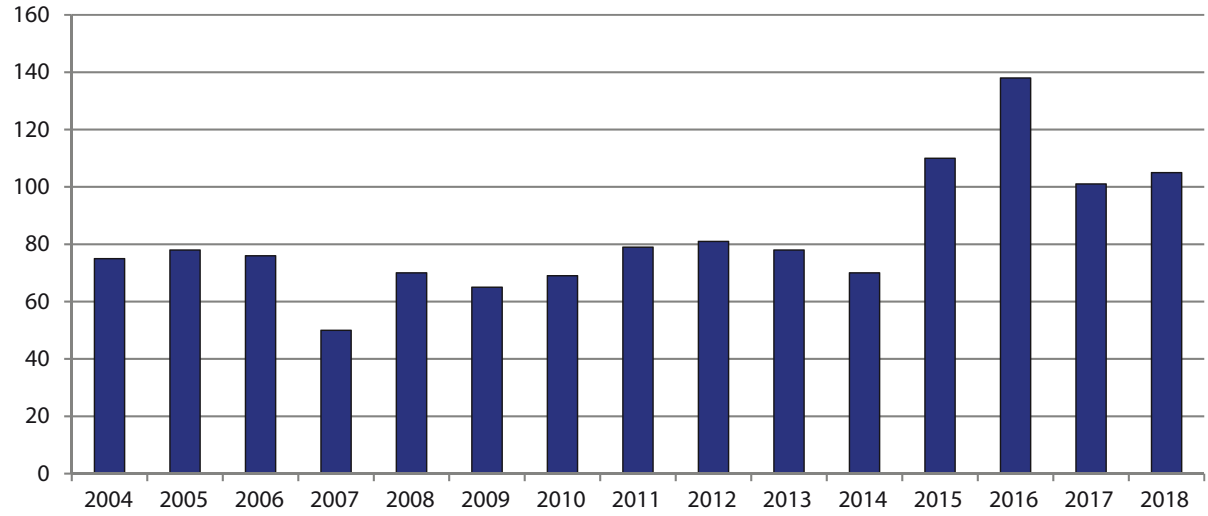


Fig. 3. *Patent dynamics for the dairy industry*

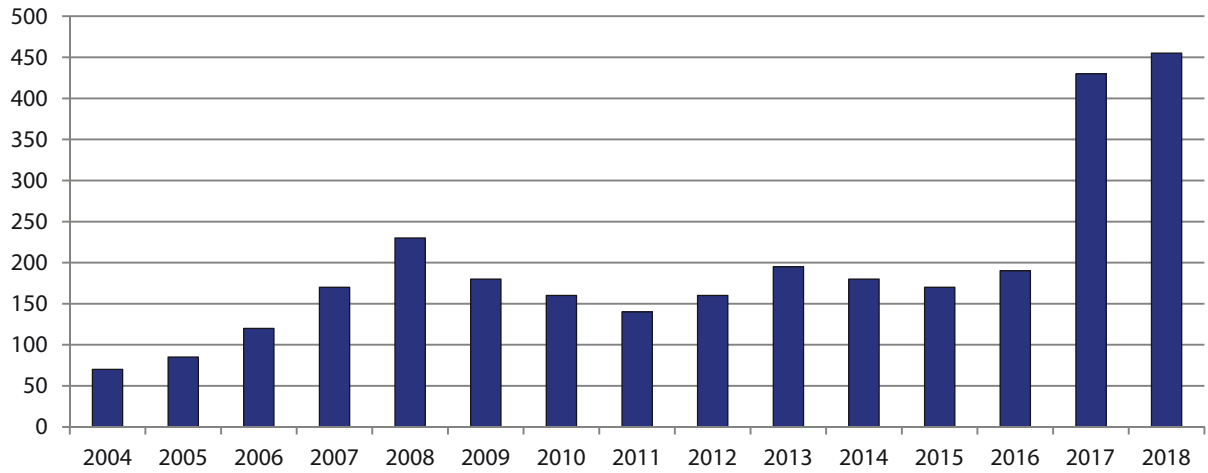


Fig. 4. *Summary of patent dynamics for metallurgy, chemical and optical industries*

gregated statistics tool was used. The obtained dynamics of patent activity in the field of dairy production is shown in Fig. 3. This field shows slight growth since 2004.

We revealed the following primary competitors of companies from the Vologda region in that field, which are Nestle SA (Nestek), Valio LTD, Danone, and Mars Inc.

The dynamics of patent activity in areas related to metallurgy, chemical industry, production of optical devices is shown in Fig. 4. It can be seen that there has been a steady increase in the number of new patents since 2017.

The main competitors are big international companies, such as Nippon Steel and Sumitomo Corporation, JFE Holdings, ArcelorMittal, SMS Group GmBh (GE) Salzgitter AG, Baoshan Iron & Steel Corporation, Morgan Construction Company, LG, Nikon, Life safety distribution GmbH and Omia International AG.

According to those patent landscapes, the strategic sectors of the Vologda region's economy are the source of new technologies, which are competitive in the local and international markets. Many priority investment projects are being implemented in the regional industries with high development potential[1]:

— Metallurgy: JSC "Severstal" Metal Coating Complex, Ladle Furnace No. 2 Unit, metallurgical production facilities.

— Chemical industry: JSC "Apatit" — construction of new fertiliser capacities, development of fertiliser production; LLC "Rusjam glass holding" — modernisation of glass container production.

— Food industry: LLC "Nestlé Russia" — construction of a factory for the production of infant formula.

— Forestry: LLC "Belozerskles" — new sawmill; "Sokol SiElTe" LLC — production of cross-glued panels; JSC "Belozersky Lespromkhoz" — increase

[1] On the list of priority investment projects (as amended on December 23, 2019) Government Resolution No. 1322, Order of the Ministry of Industry and Trade of the Russian Federation dated January 14, 2020 No. 10

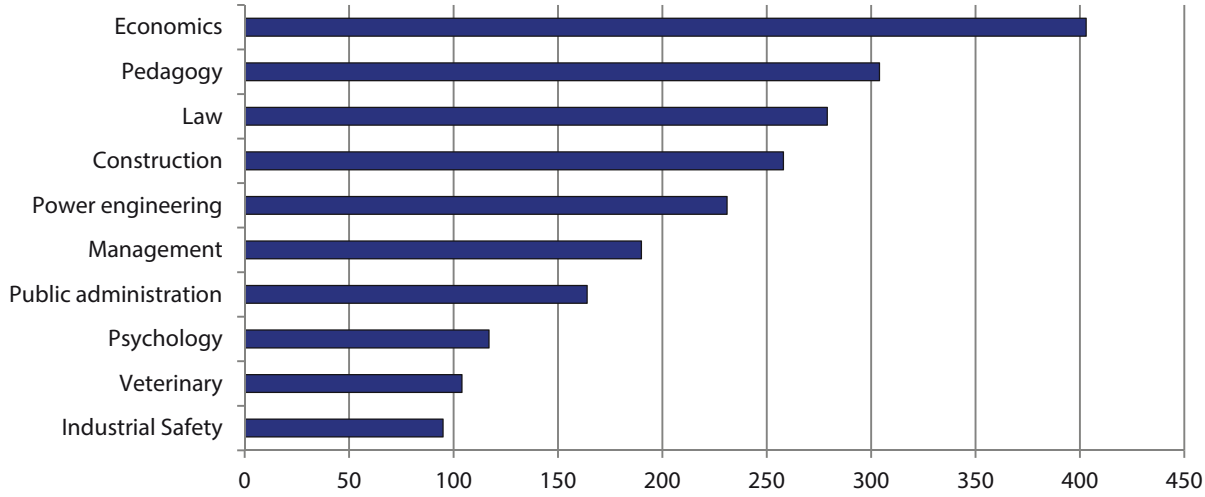


Fig. 5. *University majors in the Vologda region*

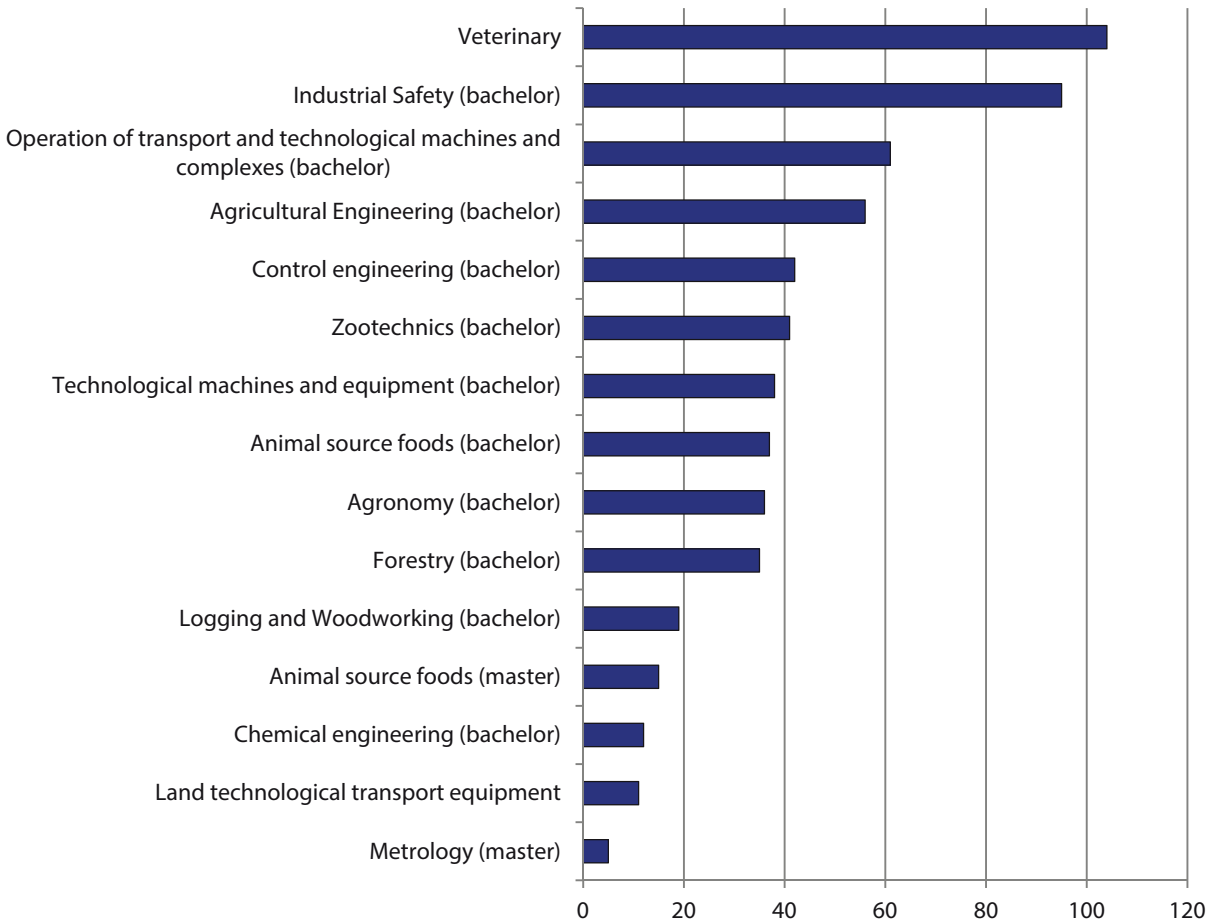


Fig. 6. *Structure of majors for the Forestry and Food industry*

in production of wood pellets; GC "Vologodskie lesopromyshlenniky", JSC "Cherepovets Plywood & Furniture Plant" — high-tech machinery for the production of large-format plywood.

In the second step of the study, we considered the features of the regional personnel policy. The modern approach to the problems of efficiency consists in recognising the decisive role of human potential; hence, there is the need to consider and assess the features of regional educational policy for a synergistic interaction between education and production. The educational and scientific potential of universities has a direct impact on the innovation process for a wide range of regional companies, but largely affects the development of enterprises in strategic sectors of the economy. The performed analysis showed that the structure of majors in state universities of the Vologda region does not correspond to the federal and regional priorities of technological development as well as the structure

of the local economy. In particular, the structure of specialties in the Vologda state universities does not correspond to the directions of the Strategies and the structure of the regional economy. Analysis of the top 10 university majors shows a bias towards the economics, pedagogy, and law (Fig. 5, 6).

Analysis of the structure of majors for training staff for the forestry and food industry shows that there are correct guidelines in the choice of directions; however, the number of graduates and the share of such specialists seems to be insufficient in terms of the needs of the regional economy.

In the third step of the study, we revealed the directions of training staff by universities and identified promising areas of training and attracting qualified personnel, considering the priorities of the technological development of the region. As a result of the analysis, such strategic industries as the food industry, forestry, metallurgy, the production of computers and optical devices were identified as promising ones. In the «food industry», there are organisations (OJSC «Educational and experimental dairy plant», Vologda State Dairy Farming Academy named after N.V. Vereshchagin), which combine research and production activities; therefore, we can consider them as a potential platform for introducing innovations into production, increasing the level of technology readiness. It is necessary to note an increase in the average monthly nominal wages of employees of organisations in the Vologda region over the period 2017–2019. In recent years, according to the data of the Federal State Statistics Service in the Vologda region, the above indicator has increased by 23.6 %, and the average wage for 2019 in the region amounted to 39,116 roubles. In the sectors «forestry» and «food industry», the average salary was 30,384 roubles and 31,229 roubles, respectively. In these sectors, remuneration is lower than the average for the region; therefore, attracting additional personnel in these sectors may require material incentives. In the industries «metallurgy» and «production of computers and optical devices», the salary in 2019 was 70,204 roubles and 63,211 roubles, respectively, and this indicator significantly exceeds the average wage in the region. Thus, there is a competitive level of remuneration, which is a serious motivation for the selection of enterprises in these industries by young professionals and qualified personnel.

After that, we examined the centres of basic and applied science, as well as production centres to understand the whole picture of the level of integration of the science, education and industry in the region. As part of the study, we have identified related research centres. A distinctive feature of such a division is the cost of R&D expenses. Within the previously identified strategic sectors of the region, the following related centres were identified:

1) Vologda Research Center of the Russian Academy of Sciences (VolRC RAS, basic science) — Vologda State Dairy Farming Academy named after N.V. Vereshchagin (centre for applied science and education).

2) Cherepovets State University (Centre for Applied Science and Education) — Vologda State University (Centre for Applied Science and Education).

The Vologda Research Center of the Russian Academy of Sciences was created by joining the Institute of Socio-Economic Development of Territories of the Russian Academy of Sciences (direction — economics) and the separate department of the Northwestern Dairy Farming and Grassland Management Research Institute. Fundamental R&D costs at VolRC RAS account for 74 % of all the expenses. At the Vologda State Dairy Farming Academy, 46 % of the costs are spent on research and development. At the Cherepovets State University, up to 67 % of the costs go to applied research, and at the Vologda State University, 81 % go to basic research, 14 % of the cost to applied research.

The spatial diagram shows the main promising industries of the region: metallurgy (black) and production of computers and optical devices (white), the dairy industry (grey), fertiliser production (hatched); centres of basic and applied science, production centres, as well as the main promising enterprises, and related universities (Fig. 7).

Thus, the proposed methodology provides clues for evaluating the region's need for staffing following the trends in developing advanced technologies within regional technological and industrial policy. This methodology assumes applying data analysis and patent landscaping approaches. Moreover, it is essential to consider the economic features of the regional development, the implemented and prospective investment programmes, the indicators of the strategy of the socio-economic development of the territory, the needs of the primary local enterprises in highly qualified personnel, and the possibilities of universities for training personnel in the identified priority majors to forecast the staffing of the region.

Conclusion

The approaches to the selection of priorities at the state level should be based on the capabilities of regions. At the same time, the choice of priorities for the development of the region's industry

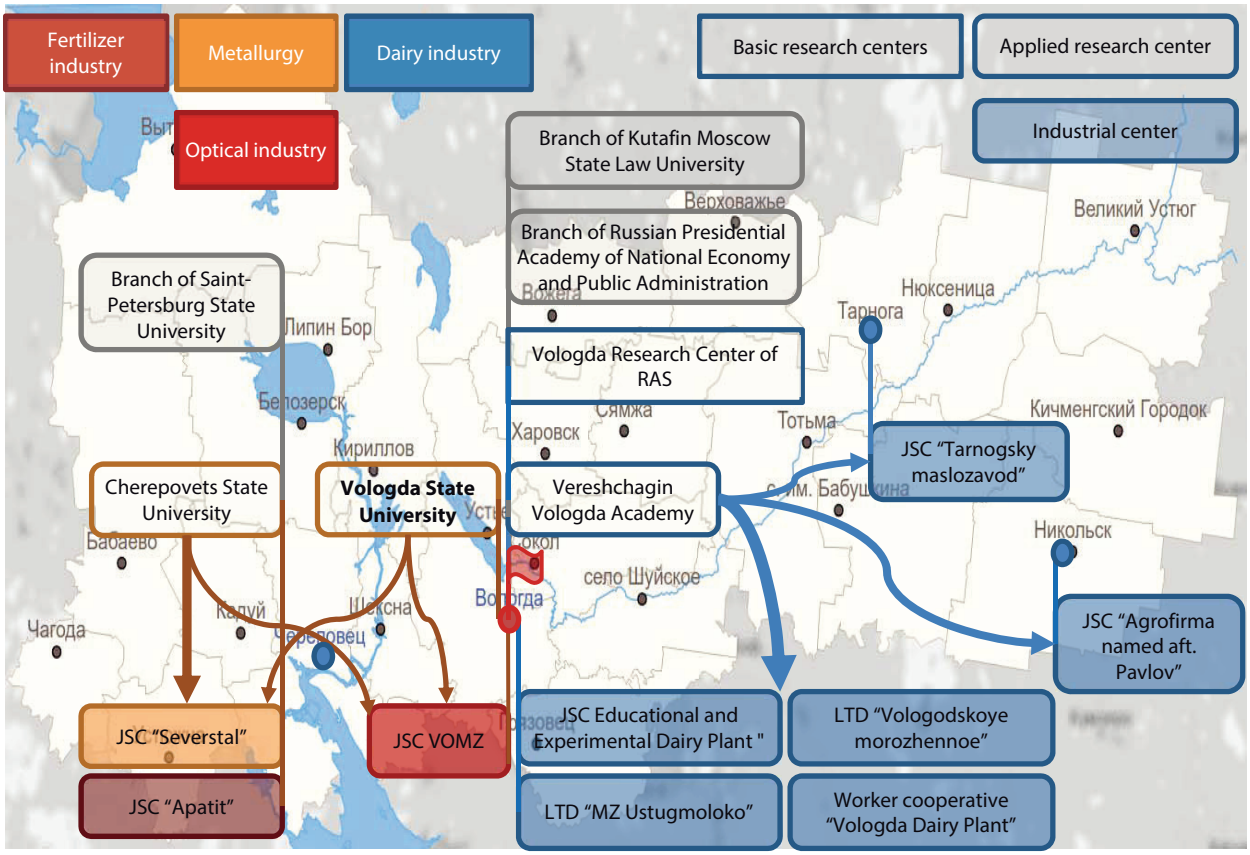


Fig. 7. *Map of distribution of educational, industrial and R&D centres of Vologda region*

should be closely linked to the possibilities of personnel training; therefore, it is necessary to «fine-tune» the structure of specialties for training specialists in the region's profile. The paper proposes a methodological approach to identifying promising areas of training and attracting qualified personnel, considering the priorities of the technological development of the region. The example of the Vologda region shows that the R&D background and coherence of local universities' majors with the personnel needs of promising industrial enterprises is the essential factor in building up the country's human resources to follow the strategies of technological and spatial development. Besides, the study demonstrates that the region's needs for human resources can be analysed at the federal, not at the local level. Of course, the regions should be involved in that process, but the final figures should be controlled at the federal level[1]. The formation of a qualitative forecast of technological development is a large-scale project. Therefore, it is necessary to employ the expert and consulting function of the scientific and educational society, to attract research institutes of the Russian Academy of Sciences and leading universities in the regions to participate in the formation and assessment of forecasts.

The future development of this research consists in the creation of the methodology for quantitative assessment of the regional need for professionals in particular industries. Any regional labour market is driven by several actors, which aim for their independent goals. As far as we have the leading regional "producers" of labour (universities) and primary "consumers" of it (enterprises) detected, it seems that agent-based models can be applied to obtain the quantitative assessments in different scenarios. Namely, the Dosi's K+S labour market model (Dosi et al., 2018) could be modified and run to find the scenarios that guarantee good staffing for the enterprises.

This methodology will be required to consider the demographical and economic statistic databases as well as corpora of full-text R&D documents.

[1] Order of the Ministry of Science and Higher Education of the Russian Federation, April 3, 2020 No. 550 Retrieved from: https://www.garant.ru/products/ipo/prime/doc/73954074/

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