L.N. Bannikova

L.N. Boronina

I.I. Sholina

UDC 331.5.024.52: 332.1: 62-057.4

Best Practices of Simulating New Approaches and Tools for Assessing Regional Demand for New-Generation Engineering Workforce

Ural Federal University
L.N. Bannikova, L.N. Boronina, I.I. Sholina

In the context of a new paradigm of planning the demand for engineering workforce, the prediction should be formed by each constituent entity of the Russian Federation from the points of view of largest employers and the system of professional education. This stipulates the transition from strict calculation algorithms to a variety of approaches and methods and their free choice. The article discloses the assessment models for evaluation of engineering labor market demand.

Key words: forecasting, regional engineering labor market, models for assessing enterprises' demand.

The issues of predicting economy's needs and demand for professional workforce, including specialists with engineering education, have been widely discussed over the past few years. Researchers identify two levels of forecasting regional needs in professional workforce: a strategic level (creating long and mid-term forecasts) and operational predictions, determined by an annual amendment of prediction results in line with the employment rate monitoring and taking into consideration the employment of professional education system's graduates [1, p. 54].

Dividing the object of research into qualitative and quantitative workforce needs and indicating the corresponding methods of data collection and processing allows for determining three types of workforce forecasting. The evaluation of quantitative needs is a traditional sphere of economic forecasting. The quantitative criteria, as a rule, are used by the governmental agencies involved in the system of forecasting professional workforce, and large employer companies that execute the process of corporate workforce planning. The quantitative needs are determined by using regulatory, staff, balance methods, method of economical mathematical simulation, statistical methods, methods of extrapolation and expert evaluation, as well as their combination or other methods suitable for acquiring corresponding indicators. Having said this, the predomination of quantitative (economic) methods for workforce demand evaluation does not eliminate the existing misbalance between the structure of engineers' training and the unsatisfied employers' demand for qualified engineers. The quantitative strategies for workforce demand evaluation today do not solve the problem of engineers' competences deficit. This predetermines the need to find conceptually new approaches allowing regulating the system of supply-and-demand equilibrium on the labor market.

The process of forecasting qualitative indicators of the engineering labor market lies mostly in the area of managerial forecasting and is, in its essence, a simulation of alterations in the engineers' employment structure based on the competence-based approach. Foresight technologies applied in managerial forecasting combine various methods of managerial diagnostics (SWOT-analysis, brainstorming, scenarios, development of technological roadmaps, method of imitative simulation, etc.) with sociological tools of various polling types. However, the foresight approach is used, as a rule, when conducting large-scale strategic research relating to the formation of a list of on-demand competences for the field of technical innovations [2].

The advantage of sociological forecasting is the opportunity to use a combination of quantitative/formalized and qualitative/non-formalized methods for data collection and processing when working with both large and small, exclusive data sets in the context of an item-by-item research and in compliance with the specifics of researched enterprises. The transition from "demand for the workforce (professional perspective)" that is determined by employers' surveys to the "demand for the educational level and profile (educational perspective)" is one of the most difficult stages in the development of long-term and mid-term workforce forecasts. Such contradiction can be overcome by using forecasting of competences and qualifications needed for a particular workplace in order to determine prospective demand for engineering workforce of large employers. In order to conduct mid-term forecasting of competences and qualifications, the method of sociological analysis of qualifications may be used. Such analysis includes enquiry of engineers, managers of engineering projects at enterprises, analysis of workflow organization. There should be a thorough list of qualification needs stated as a result of this method's application. They should be strictly connected with particular work places. The identified deficient competences, the discrepancy in competences' supply and demand on the labor market should correlate with the National System of Competences and Qualifications in order to determine desirable educational majors that would form the required learning outcomes.

In June 2015 the Ministry of Labor and Social Protection and the Ministry of Education and Science of the Russian Federation approved a new methodology for calculating mid-term and long-term perspective of the professional workforce demand [3]. The basis of this methodology is the use of methodological and regulatory-juridical support of the national system for workforce forecasting. The forecast of the demand for professional workforce should be formed by each constituent entity of the Federation in line with the needs of the largest regional employers. The key role in development of the new forecasting system is given to the system of professional education.

The cornerstone for the formation of new-generation engineering workforce of the Sverdlov oblast/region (RF constituent entity) is the Ural Federal University. In order to implement the new paradigm of regional forecasting system the research group of the Higher Engineering School of the University has made an attempt to form new models for evaluation of the demand for engineering workforce.

Simulation of new approaches and tools for planning the demand for new-generation engineering workforce is based on three core conceptual preconditions. First of all, it is about measuring and assessing the demand for engineering specialists in line with the algorithms systematically interconnecting not the quantitative, but, before all, **the qualitative characteristics** of the engineering labor market state on a regional level. It is worth noting that the qualitative methods of evaluation are still on the evolvement stage, and there still are no flawless techniques for assessing the need in skills and qualifications. Alongside with these, most researches (economists, sociologists, psychologists) agree that in order to define the needs in particular engineering workforce, sets of professions, qualifications, competences, it is needed to exploit the qualitative methods of forecasting changes in the employment structure of one or another profession and level of education.

Secondly, for an independent evaluation of region's workforce demand it is necessary to take into account the innovation policy

ENGINEERING EDUCATION 19'2016

of industries and territories, to determine both the prospective leader by their level of innovative activity and level of production, and the low-tech and low producing industries and manufactures. Finally, the qualitative assessment of the demand for regional workforce should be run in the context of the interactive planning paradigm based on the principles of full and continual participation and resource provision of all the social interaction agents – government, industry and education.

The methodological basis for simulating new approaches and tools for demand assessment is the competence-based approach. This approach is aimed at finding solutions to the problem of engineers' qualifications deficit, determining the existing and the expected levels of engineering competences and qualifications development. The potential of competence-based approach introduction to the system of professional standard, unfortunately, is not reached. Professional standards methodology mostly uses the functional, not the behavioral approach. The developers of professional standards based them on their functional structure, knowledge, skills and attitudes, and not on the behavioral models, professional and production aims, etc. Thus, there still is a major contradiction between the system of training engineers and the new requirements from the professionals' labor market.

The requirements towards forecasts reliability lead to the necessity of applying integrated research strategy using non-linear (parallel-sequential) technologies for demand assessment. Key attributes of this technology are the sequential exchange of research information and the integrative calculations in line with the item-by-item identification of geographical, professional, industrial and functional characteristics of the demand for workforce. In other words, the key research objective is not just to assess one and the same object by using different assessment methods, but, to a greater extent, to refine and assess the advantages of various tools for measuring demand for qualifications on different objects, suitable for specific and each time different aims. Exploitation of a mixed research strategy "Hourglass Strategy" and the triangulation principle gave an opportunity to combine elements of formalized and non-formalized research approaches for a holistic and deep analysis and to find solutions to a wide spectrum of research objectives. Hourglass clock analogy indicates specific features of the research strategy, its temporal and methodological peculiarities, variable ability to use different models and methods on different temporal stages of research, decomposition of models and methods divergently.

As a result of this research strategy exploitation five prediction models occurred for forecasting qualitative parameters of regional engineering labor markets: the stakeholder model for assessment of learning outcomes, the model for assessment of innovative behavior of regional enterprises, the interactive model, the model for assessment of learning outcomes based on the CDIO Syllabus and the local model for assessment of particular competences of design engineers' professional activity.

The stakeholder model for assessment of learning outcomes is aimed at finding discrepancy in the assessment of importance and existing competences' development level of future engineers (graduates of engineering majors in Sverdlov region). The specifics of the model are the big body of data and the application of formalized methods for data collection and processing. Survey method – questionnaires. Expert team included faculty members of engineering majors from Ekaterinburg HEIs (N=146), practicing engineers of large regional enterprises (N=240), PhD students in STEM (N=88). A modular type of questionnaires (inclusion of similar blocks on assessing learning outcomes and competences) allowed for conduction of stakeholders' opinion comparative analysis.

Overall, the results of expert polling have not indicated any equivalence in assessments on the scale "importance-existence" for any competence. There is a visible gap between the desirable by the industry and the existing level of engineering graduates competences. Most severe discrepancy has been disclosed by all groups of experts in such competences, as "experience of interaction with real sector of economy" (a gap of 1.5 times), "comprehensive understanding of the chosen industry, understanding economic context of its functioning" (a gap of 1,4 times).

The need to find causes of stakeholders' assessments diversity led to the creation of the second research model – **the model for assessment of innovative behavior of regional enterprises.** The aim of the model is to identify special features and problems of managing innovative research and developments at Ural enterprises. A sample selection included 16 enterprises of key regional production industries. Survey method – formalized expert survey. The expert team included heads of scientific research centers and scientific technical departments of enterprises.

In the opinion of some regional experts, the current functional structure of scientific, educational and industrial sectors of the Sverdlov region in the context of its innovative development indicates that the region is on the beginning stage of the regional innovation system formation. The collected data allowed not only to segment real sector enterprises of the regional economy, but also to identify the dominant industrial type of the region. The results of the survey show that there are only two enterprises belonging to the leader industry – a competitive industry of the new technological wave. The overwhelming majority of enterprises (nine out of sixteen) were classified as belonging to stable industries of the old technological wave. The key conclusion of this model's application is the identified need for monitoring analysis of enterprises' innovation activities. This would lead to the development of long-term plans (requests to HEIs for training prospective specialists, joint R&D themes and projects) and mid-term plans (creation of professional development programs, possible engineering services, etc.); it would permit the correction of long-term and mid-term educational programs and scientific research activity.

The interactive model played a role of a "pivotal shaft" within the hourglass strategy. The interactivity in the name of the model has double meaning. On the one side, "interactive" indicates direct on-sight interaction with employers, working with them in the real-time mode. In this context the interactive model can be seen as a model of deep dive research ("immersion research" model) that focuses on the issues of identifying demand for workforce and finding key competences. On the other hand, similarly to the interactive models in mechanical engineering – models of reliability between the motion paths and the choice of reference system, our model discovered the reliability between competence paths and the specifics of companies' innovative behavior.

The immersion of the research has been assured by the transition from traditional quantitative, formalized assessment methods to the qualitative research methods. For data collection, a non-formalized (deep) interview with enterprises' representatives has been conducted. The data was processed by a thematic analysis of interview scripts with the use of program software. Two large enterprises, identified by the second model as having different innovative statuses and industry types, became the objects of research here. The enterprises represented two traditional leading production industries of the Sverdlov region – metallurgy and mechanical engineering industry. The metallurgical enterprise has been positioned to the "stable industry, but saving its competitiveness only due to the low production costs"; its innovative status is average. The mechanical engineering enterprise has been positioned to the "problem industries": the enterprise maintains good positions on domestic market, but had lost its positions on the global market due to its technological inferiority; its innovative status is low. Before conducting the field study a hypothesis has been proposed that the industrial and innovative statuses influence the assessment of engineering specialists' competences paths.

The survey has been conducted in line with the methodology of thematic text analysis. After studying interview scripts and conducting secondary review of text data a generalization of source codes has been made. The system of codes has been presented as follows: innovation development, assessment of modern engineering education, attitude towards cycle education, competence model, planned proportion of Bachelors and Masters in engineers' training, channels for recruiting specialists, and demand for graduates of regional HEIs.

A comparative analysis of enterprises' behavioral strategies indicated one common and highly representative feature – all respondents underlined the low level of competences of regional HEIs' graduates and demonstrated negative attitude towards cycle education of engineers.

Finding cause-and-effect relations between elements of data sets within the item-by-item research showed that such extracts as methods and character of demand forecast, sets of competences by the types of engineering activity, character and mechanisms of innovation development lie in the area of determinational interconnection. In particular, differentiating competences according to the types of engineering activity, organizational mechanisms for their formation correlate with the development/ functional strategy implemented at an enterprise. The metallurgical enterprise with an average innovative status, belonging to the stable industry, features simulation of a new type of engineering activity (innovation engineer) with a corresponding set of competences of system and spherical engineering; its preferred network forms of cooperation with HEIs are Specialized (Company-based) Departments and Dual Master Programs. The mechanical engineering enterprise with low innovative status and a survival business strategy is focused on the formation of competences in line with the qualification and functional engineering design workplaces within the industry; a high level of fundamental education is prioritized in the structure of general professional competences; its prioritized organizational form serving for the purpose of acquiring extra practical competences is the corporate system of professional development programs. A set of personal competences differs as well depending on the innovative status of an enterprise: average status – stress resistance and self-motivation; low status – personal responsibility of an engineer.

The survey indicated restrictions in identifying quantitative needs of enterprises in engineering workforce. The enterprises use different levels of forecasting – corporate and industrial. Key corporate method of forecasting the demand for engineers is the functional analysis of workplaces. The method of expert survey is used when speaking of the industrial forecast. Prioritized and independent of the enterprise's development character is the mid-term forecasting for upcoming 3-5 years.

The results of the interactive model research have been verified at the next stage of research. **The model for assessment of learning outcomes based on the CDIO Syllabus** turned out to be a role model for the determination of required competences for the new-generation engineering workforce. The basis of the Worldwide CDIO Initiative is formed by the stages of any engineering product's lifecycle: Conceive – Design – Implement – Operate. CDIO Syllabus is a system of knowledge, skills and personal attitudes necessary for modern engineers. The CDIO Syllabus lies in the essence of reorganization of modern programs of engineering education all over the world at technical HEIs.

The CDIO Syllabus map has been tried out on the design engineering profession – one of the most desirable majors, especially in the field of regional mechanical engineering. The subject of assessment – competences of design engineers of a large mechanical engineering enterprise of Sverdlov region. The method for data collection is the formalized interview with managers of a large engineering project within the company. In the context of the embraced integration the formalized interview appeared as a sequel to the interactive model. Such integration allowed relating the non-formalized and formalized data in order to confirm the results of the questionnaire in all its varieties. The depth of a gap between the existing level of the set of competences and the employers' expectations on particular competences within the CDIO Syllabus has been determined and assessed in line with the professional qualification structure for design activities of three positions – design engineer, leading design engineer and manager of an engineering project.

The assessment of dynamics of design engineers' professional development on work position levels indicated that the volume of requirements and the importance of the expected competence increase from the starting level of qualification to a higher position more drastically (40% on average) than the actual level of engineers' expertise (20% on average). This supports the conclusion that the pace of overcoming the gap between the real and the expected by employers level of competences is not sufficient. The causes for such contradiction can be both personal limitations and inaccurately formed work conditions. In order to solve this problem a full-time working system of professional development should be organized; support and stipulation of design engineers' self-education should be provided. In the current case, this involves the organization of professional development programs on not just the existing production technologies, but on the design and development of new technologies.

This recommendation has been taken into account by the researchers when developing the last model – **the local model for assessment of particular competences of design engineers' professional activity.** Researchers calculate that professional development of highly qualified design engineers, and especially managers of engineering projects, takes up to 10 years of work within a large production enterprise. The current research shows that if this process is result-oriented and organized on the basis of modern technologies for professional development management, then it can be shortened by several-fold – down to 1,5-2 years. This may lead to dissolving or at least softening "qualification deficits" on the design engineering labor market. Generalization of the research results on professional competences of design engineers for mechanical engineering enterprises serves as a basis for the development of innovative programs of adult education with an aim to minimize the "qualification deficit" on the design engineers' labor market of the Ural region [4].

Thus, the developed models for the assessment of qualitative demand for the new-generation engineering force permitted specialists of the Higher Engineering School (based on their deep analysis of the large regional employers' interests and the specifics of their innovative behavior) to segment the routs for interaction between HEIs and enterprises of the real sector of the economy; to form the basis for an integrative system of scientific research and distinguished solutions on the assessment of workforce demand, to coordinate the expected learning outcomes on design and implementation stages of the engineering education programs.

The research is conducted with financial support from the Russian Science Foundation in the framework of the project #57-РНФ/15 "Comprehensive research of a system for training engineering workforce with an aim to enhance tools for demand planning and in line with the restructuring of the network of federal educational organizations of higher education"

REFERENCES

1. Vasilieva Z.A. Problemyi modelirovaniya kadrovoy potrebnosti regionalnoy economiki [The Modeling Problems of Recruitment Needs of Regional Economy] / Z.A. Vasilieva, I.V. Filimonenko // Bulletin of the Pacific State University of Economics. – 2012. – № 4. – pp. 46–57.
2. Sigova S.V. Formirovanie perechnya vostrebovannyih kompetentsii: pervyii opyt Rossii [Creating the List of Competences in Demand: First Russian Experience] / S. V. Sigova, A.G. Serebryakov, P.O. Luksha // Lifelong Education: the XXI century. – 2013. – T. 1, № 1. – pp. 61–71.
3. On Approval of Policy Directive on the System of Mid-Term and Long-Term Forecasting of Local Employment with an Aim to Plan the Demand for Training at Educational Institutions, Executing Programs of Vocational Education and (or) Higher Education on State-Funded Basis, and the Methodology for Calculating for Mid-Term and Long-Term Perspective the Demand for Professional Workforce of the Russian Federation Constituent Entities, the Industry-Based Economy and the Largest Employers [Electronic resource]: Order No. 407 of the Ministry of Labor and Social Protection of the Russian Federation, Order No. 641 of the Ministry of Education and Science of the Russian Federation from 30.06.2015. – URL: http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=EXP;n=629950, free. – Title from the screen (date of reference: 26.03.2016).
4. Isaev A.P. Professionalizm ingenera-konstructora: analiz, otsenka I sovershenstvovanie [Professional expertise of design engineer: analysis, assessment and improvement] / A.P. Isaev et al. – Ekaterinburg: UrFU, 2014. – 152p.

UDC 35:005.342

Humanization of Engineering Education: Current Challenges in Russia

Siberian Transport University
T.A. Rubantsova

T.A. Rubantsova

The paper deals with humanization of today's engineering education and analyzes interconnection between science and education in philosophical perspective. The author investigates different methodological approaches to engineering education, which were applied in Russia before and after the Revolution, in terms of humanization and dehumanization of the society.

Key words: humanization and dehumanization of the society, engineering education, technical education, scientism, education.

Engineering education in Russia is currently developing under complicated conditions due to significant social changes and fast technological progress. There is also an important question whether it is necessary for technical education to consider individual interests and needs. To answer this question, one should investigate engineering education as a social institution.

Engineering education as a social institution was established when the first complicated technical objects were created and the technics became the major factor boosting social development [1. p.3]. It was at the ages of Renaissance and Enlightenment when the paradigm of education was developed. This paradigm included a block of humanities, which were supposed to develop personal integrity and contribute to social positioning, as well as another block of natural and technical science disciplines necessary to understand the surrounding world.

Environmental problems, the threat of nuclear disaster, and resource depletion are the challenges which people face due to the intense development of technology. Technology is the link between theoretical knowledge and production activities and can be described as the sphere of human knowledge aiming at nature change, the bulk of human abilities and skills. J. Ellul remarked that technology is the machines that make the human being an object of manipulation revealing everything that used to be concealed. Therefore, an engineer is supposed to play a major part in designing new social reality.

In the 18th century in Russia there was a contraversion between the natural sciences and humanities representatives in the spheres of science and education. Within the framework of classical rational science there were two approaches to analyze the correlation between morals and science, ethics and knowledge. "One pole implies scientific perspective while the other one is connected with establishing, strengthening and disseminating morals, human ideals and values" [2, p. 16]. This issue is currently urgent. The correlation between humanization of education and science should be based on interconnection of technology, science, and education, which will allow determining the proportions of humanities and technical sciences contribution to worldview formation.

The intense development of technics and natural sciences made some people think that science and technics fail to play a positive role in the development of the society and engineering education cannot secure social progress. This point of view derives from the age of Enlightenment: J.-J. Rousseau developed and disseminated the