Quantitative Assessment for Training of Senior Scientific Staff

V. A. Gurtov[1], L. V. Shegoleva[2]
Petrozavodsk State University
Petrozavodsk, Russian Federation
[1]vgurt@psu.karelia.ru, [2]schegoleva@petrsu.ru

G. I. Dmitriev
Saint Petersburg Electrotechnical University "LETI"
St. Petersburg, Russian Federation
sznmc@mail.ru

***Abstract*—The human society since ancient times has questions "Whom to teach?", "What to teach?", "How long to teach?". The answers to these questions are changing along with the structure of human society, the structure of the economy. Currently, the economy requires qualified staff with a good education, and progress requires new technological ideas, the generators of which are representatives of the scientific community. Staff training for the scientific community is a separate complex and spending task. An insufficient number of graduated scientific staff entails inhibition in innovative development, and an oversupply of such graduates is a waste of state money and causes problems for the career path of the graduates themselves.**

Key words—senior scientific staff training; scientific degree; training staff planning; forecasting; labor flow

I. INTRODUCTION

The task of predicting the optimal number of scientific staff becomes relevant. The international scientific community concerns about the significant growth in the number of PhD graduate students [1]. In 2017, the European Science Foundation conducted a study of career paths of people who graduated with a PhD degree [2], in which took part about 23% of those who graduated with a degree in the last 6 years preceding the study. The survey showed that only a little more than a half of respondents work in the academic sector. Less than half of polled people work in non-academic sector and hold a position corresponding to their academic degree or at least a master's degree. The result of the study indicates a certain redundancy of trained specialists with academic degrees.

In Russia, from 2011 to 2018, 121 thousand of doctoral research scholars defended their thesis. Their average age is 32 years. At the same time, the number of researchers under the age of 40 reaches 23 thousand [3], and university workers – 24 thousand [4]. It turns out that less than a quarter of PhD graduates work in science and education, where their academic degree is in demand first of all.

Thus, the process of forecasting the demand for senior scientific staff is necessary for planning the number of enrollment to graduate school and graduation from it with the defense of a thesis.

Forecasting the needs for candidates and doctors of sciences [5] is based on the calculation of the annual additional needs, for the assessment of which it is necessary to know the amount of natural retirement of staff.

Depending on the forecasting models used, two approaches are used to assess the natural staff retirement.

II. NATURAL-AGE RETIREMENT DURING THE LABOR FLOW

For dynamic models describing the labor flow, natural retirement includes two components: death during the performance of labor functions and retirement by age. To calculate the first component, one can use ageing factor obtained from official statistics on the annual age structure of the Russian population over the past 10 years (Table 1).

TABLE I. AGEING FACTOR

Age	Ageing factor
before 25	1
25-29	1
30-34	0,999963
35-39	0,997889
40-44	0,988042
45-49	0,964374
50-54	0,925329
55-59	0,869745
60-64	0,795848
65-69	0,709277
70-75	0,579284

Thus, among researchers up to 70 years old with a scientific degree of a candidate of science, up to 5 thousand people can leave up annually at working age, among researchers who have a scientific degree of a doctor of science – up to 2.7 thousand.

Candidates of science who have reached the age of 70 years and over reach a number of 10.8 thousand people, doctors of science – 9.4 thousand [3], of them at the age of 70 years – about 3.2 thousand candidates of science and 0.9 thousand doctors of science.

If we assume that reaching the age of 70 years is the reason for the retirement of the researcher worker, then annually the natural-age retirement of candidates of sciences will be about 8.5 thousand people, and doctors of sciences – about 3.6 thousand people.

We will carry out similar calculations for the higher education sector. The annual retirement, subjected to termination of employment at the age of 65, is equal to 11.8 thousand for candidates of science, 3.7 thousand for doctors of science.

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III. THE ROTATION COEFFICIENT

The second approach is associated with the calculation of the rotation coefficient, which shows the share of annually retired personnel of the senior scientific staff (candidates of science and doctors of science) in relation to their total number in the current year and is equal to the inverse ratio of the average duration of work of these staff. For its calculation it is necessary to know the age of the beginning of labor activity, which coincides with the age of the thesis defense, and the age of retirement. If we assume that the age of the retirement for a candidate of science is 65 years, and for a doctor of science - 70 years, then the rotation coefficients on average will be 0.031 and 0.043.

It is important to know that for different branches of science and different sectors of the economy, these values differ significantly. Table 2 shows the average age of defense of a candidate thesis in the context of groups of scientific specialties and places of work of doctoral research scholars.

TABLE II. THE AVERAGE AGE OF DEFENSE OF A CANDIDATE THESIS

Specialties	Universities	Academy of Sciences	Other Research Institutes, Industrial Enterprises	Other organizations
01.01.00 Mathematics	30	28	28	29
01.02.00 Mechanics	30	30	31	31
01.03.00 Astronomy	33	30	39	39
01.04.00 Physics	30	31	32	31
02.00.00 Chemistry	29	28	30	30
03.01.00 Physicochemical Biology	30	29	31	32
03.02.00 General biology	31	32	33	34
03.03.00 Physiology	31	30	33	33
05.01.00 Engineering geometry and computer graphics	31		34	31
05.02.00 Mechanical engineering	31	40	31	33
05.04.00 Power, metallurgy and chemical engineering	31	29	39	33
05.05.00 Transport, mining and construction engineering	31	29	30	34
05.07.00 Aircraft, rocket and space technology	30		33	35
05.08.00 Shipbuilding	34	31	31	33
05.09.00 Electrical Engineering	31	28	31	32
05.11.00 Instrument-making, metrology and information-measuring devices and systems	29	33	34	32
05.12.00 Radio engineering and communication	30	31	32	32
05.13.00 Computer Science, Computer Engineering and Control	30	30	30	31
05.14.00 Energetics	30	32	33	32
05.16.00 Metallurgy and materials science	30	32	32	35
05.17.00 Chemical Technology	29	32	34	32
05.18.00 Food Technology	31	29	34	34
05.19.00 Technology of materials and products of textile and light industry	31		29	35
05.20.00 Processes and machines for agroengineering systems	32	36	30	33
05.21.00 Technology, machinery and equipment for logging, forestry, wood processing and chemical processing of wood biomass	32	34	32	33
05.22.00 Transport	31	32	39	35
05.23.00 Sivil engineering and architecture	31	31	33	32
05.25.00 Documentary Information	35	36	34	38
05.26.00 Human Safety	32	30	36	35
05.27.00 Electronics	29	31	34	32
06.01.00 Agronomy	32	33	33	33
06.02.00 Veterinary and Zootechnics	31	32	33	35
06.03.00 Forestry	30	32	32	35
06.04.00 Fisheries	38	31	40	44
07.00.00 History and Archeology	34	33	39	33
08.00.00 Economy	32	31	33	32
09.00.00 Philosophy	35	34	43	35
10.01.00 Literature	33	37	36	32
10.02.00 Linguistics	33	34	33	31
12.00.00 Law	32	29	34	32
13.00.00 Pedagogy	38	40	44	39
14.01.00 Clinical medicine	33	32	33	35
14.02.00 Preventative medicine	35	30	37	40
14.03.00 Biomedical Sciences	33	32	34	37
14.04.00 Pharmacy	30	27	31	33
17.00.00 Art history	37	43	33	38
19.00.00 Psychology	34	32	36	35
22.00.00 Sociology	32	32	34	33
23.00.00 Political science	32	31	36	32
24.00.00 Cultural studies	36	39	34	36
25.00.00 Earth sciences	31	31	34	34

The youngest candidates of science are employees of research institutes engaged in research in the field of the group "01.01.00 Mathematics". Researches from the group "13.00.00 Pedagogy" have the greatest age of thesis defense. Researches from the groups "09.00.00 Philosophy", "06.04.00 Fisheries", and "17.00.00 Art History" also have high age values.

Fig. 1 and 2 show the values of rotation coefficients for candidates and doctors of sciences in the context of groups of scientific specialties and sectors of the economy: universities, institutes of the Academy of Sciences, other research institutes, design bureaus, and other organizations.

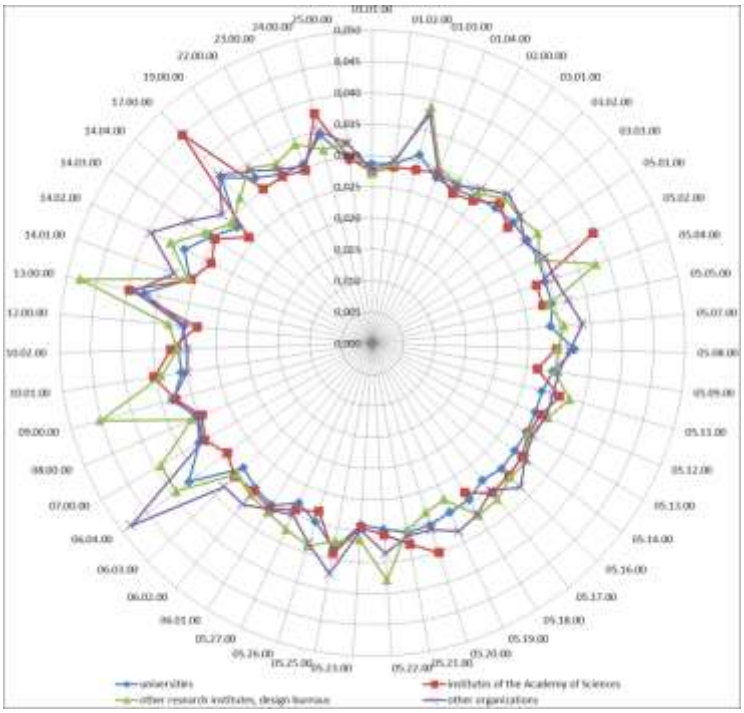

Fig. 1. Values of the rotation coefficient for candidates of science

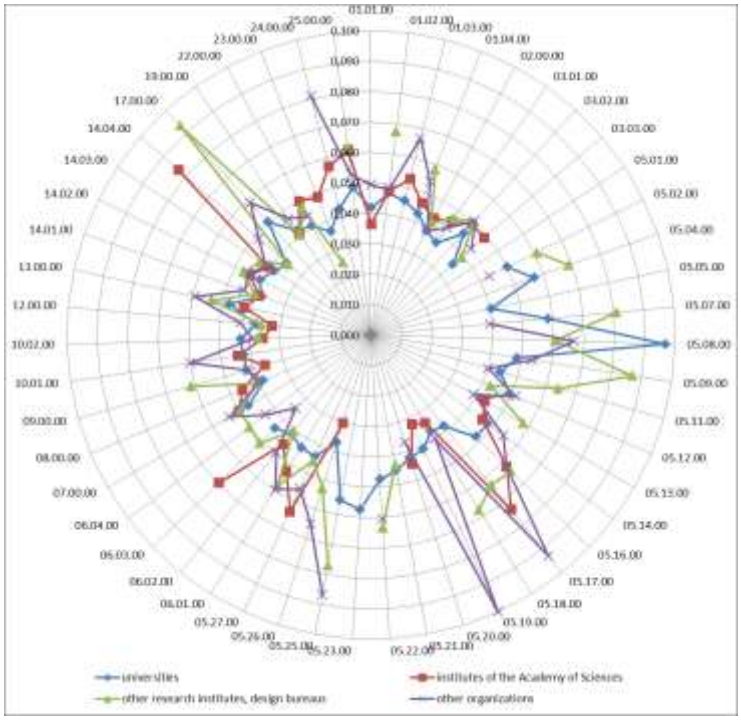

Fig. 2. The values of the rotation coefficient for doctors of science

With an equal age of graduation, the rotation coefficient is higher for those scientific specialties where the age of defense is higher. For doctors of sciences employed in universities, a high value of rotation coefficient is observed for scientific specialties from the group 05.08.00 Shipbuilding, for the Academy of Sciences – 05.17.00 Chemical Technology.

For applicants for a medical degree working in medical institutions, the defense of candidate thesis takes place at a more mature age (Table 3).

TABLE III. AVERAGE AGE OF DEFENSE OF A THESIS IN MEDICAL SPECIALTIES

Specialties	Medical institution	University	Academy of Sciences
14.01.00 Clinical medicine	35	32	32
14.02.00 Preventative medicine	41	35	30
14.03.00 Biomedical Sciences	37	33	32

As a result, the rotation coefficient for these senior scientific staff will be higher and will be equal to: 0.034, 0.042 and 0.036, respectively.

IV. CONCLUSION

To predict the needs of the economy for senior scientific staff, it is necessary to conduct quantitative assessments of the annual natural-age retirement of candidates and doctors of sciences, taking into account the specifics of scientific research and their place of work. The article presents quantitative calculations of these indicators for two types of models in the context of groups of scientific specialties and sectors of the economy.

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