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SYSTEMATIC APPROACH TO THE ANALYSIS OF THE STRUCTURE OF THE SCIENTIFIC INFRASTRUCTURE OF KAZAKHSTAN

Abstract

This article employs a systematic approach to examine the structure of Kazakhstan's scientific infrastructure, emphasizing its role as a harmonious network of organizations dedicated to fostering entrepreneurship in the realm of science and technology. The central aim is to comprehensively assess the scientific infrastructure of Kazakhstan, encompassing its constituent elements, the overall state of science in the country, its scientific, scientific-technical, and human potential. Furthermore, the article conducts a meticulous examination of the conditions across various scientific domains. Through this analysis, the article identifies a complex web of connections that imbue the scientific infrastructure with systemic attributes, enabling a comprehensive understanding of their diversity, quality, and distinct roles in its development. Notably, the author underscores the pivotal role played by the state in shaping and advancing the scientific infrastructure, as it possesses the capacity to pool the essential resources required for its efficient operation. This is essential for establishing systemic innovation within the economy, thereby incentivizing economic entities to pursue novel advancements. Besides, this article offers a systematic exploration of Kazakhstan's scientific infrastructure, highlighting its significance as a facilitator of innovation and commercialization of scientific and technical research.

Key words: infrastructure, scientific infrastructure, innovation, researchers, internal costs, financing, technological development, human potential.

Introduction

Modern Kazakhstan is undeniably driven by an unwavering commitment to creating an innovative economy as the cornerstone of its socio-economic development. In this pursuit, the concept of innovation development has become an indispensable catalyst, supporting the country's aspirations for significant economic growth and the improvement of its citizens' well-being.

The success of this endeavor hinges on the intricate interplay between the effectiveness and dynamism of scientific efforts and the financial adaptability of the scientific sphere, both of which are heavily dependent on the state of scientific infrastructure [1]. Scientific infrastructure, essentially, encompasses a multifaceted combination of social, production, organizational, economic, technological, and informational functions within research centers. It holds a unique position within the broader scope of science, serving as a fundamental structural element of the "soft power" of the scientific system. This role is underscored by its direct and interrelated connections with all other aspects of scientific activity.

Remarkably, in developed countries, scientific infrastructure plays a crucial role in the economy, distinguished by its extensive scale and profound impact on Gross Domestic Product (GDP) and the overall functioning of economic systems. It extends beyond mere existence and becomes an integral component of national and regional models. Therefore, understanding the complex interaction between infrastructural structure and the broader scientific infrastructure in the economy becomes imperative, requiring effective measures for improvement [2].

At the core of this evolution lies the pivotal role played by the state in shaping and developing scientific infrastructure. Indeed, only through the state's ability to accumulate the necessary resources can efficient infrastructure operation be ensured—a critical foundation for stimulating systemic innovations in the economy and encouraging economic entities to embark on new developmental trajectories [3].

In light of these considerations, it becomes evident that scientific infrastructure cannot be viewed in isolation; rather, it should be perceived as an integral aspect of a broader innovation infrastructure. This holistic perspective portrays a complex, multifaceted, and multilayered system that serves as the foundation for advancing the country's economic prosperity and enhancing the quality of life of its population.

Materials and methods

This study employs an interdisciplinary approach to investigate the scientific infrastructure of Kazakhstan, examining its components, the overall state of science, its scientific, scientific-technical, and human potential, and conducting a detailed analysis in various scientific fields.

Methodology: Within this research, a combination of research methods was utilized, including logical and comparative analysis, synthesis, systems analysis, statistical analysis, and analytical methods. The method of systems analysis was particularly applied to study the scientific infrastructure. The essence of this approach lies in considering a phenomenon or object as a complex organizational entity, followed by the division of the studied object into its constituent elements or the identification of characteristic subsystems, along with the determination of connections between them, the existence of which characterizes the object as a system and defines its internal dynamics [3, p. 13].

Materials: The study relies on a wide range of information sources to substantiate its analysis. These sources include scientific articles from both domestic and foreign authors, data obtained from the Bureau of National Statistics ASPR (Agency for Strategic Planning and Reforms) of the Republic of Kazakhstan, information from the Ministry of National Economy of the Republic of Kazakhstan, and materials obtained from various research groups specializing in the field of scientific infrastructure in Kazakhstan. The data collected from these sources undergo thorough analysis and evaluation, enabling researchers to gain a comprehensive understanding of trends, characteristics, and key components of the scientific infrastructure. Such an approach ensures that the research results are based on a reliable database and analysis, enhancing the reliability and justification of the research findings.

Main provisions

Systematic approach considers the scientific infrastructure as a complex system consisting of a set of interrelated elements that are focused on achieving the set development goals, taking into account both internal and external factors. The systematic approach allows for dynamic accounting of multiple factors and considering them in conjunction with various trends in the development of the external environment of the scientific infrastructure [1, p. 56].

The purpose of this scientific article is to identify the characteristics of the systemic approach in the study of the scientific infrastructure in Kazakhstan, and to analyze the overall state of the development of science, including its scientific, technological, and human potential.

In recent years, the greatest grouping of all infrastructure elements, all spheres of production and science, as well as their complex development has been achieved in the structure of specialized scientific and production zones (technopolises, science parks, technology parks). These are territories where research, design and production companies that receive special government support are concentrated. They are created on the basis of universities, research organizations, or by converting ordinary industrial and production zones. The practice of global economic development shows that targeted technological changes allow the economy to quickly emerge from a state of long-term depression. High technologies allow to significantly increase efficiency, as well as reduce prices, increase production volumes, improve trade and competition [4].

The current situation in the field of innovation is characterized by the intensification of the process of convergence, which means the convergence of individual economic sectors and scientific aspects.

Through convergence, new progressive developments emerge at the "junction" of various sciences, educational sectors, and economic sectors. In addition, another characteristic trend is the increasing importance of scientific infrastructure for the national economy. Today, scientific infrastructure is essential for any country that wants to develop harmoniously in order to maintain itself among the leading world powers [5].

The scientific infrastructure of Kazakhstan includes academies of sciences, such as: The National Academy of Sciences of the Republic of Kazakhstan (NAS RK) [6];

The Kazakh Academy of Natural Sciences (KazANS) [7];

The National Institute of Aerospace (NIA RK) [8].

The NAS RK includes the most advanced department of Kazakh scientists - full members (academicians) and corresponding members of the academy. The NAS RK includes 228 members (155 academics and 73 corresponding members), 17 foreign and 110 honorary members of the NAS RK, 41 collective members and 23 professors of the NAS RK [6].

These academies operate in the form of a republican public association with fairly limited functions in the field of management and financing of scientific activities.

Literature review

To determine the extent of the study of this problem, the following were analyzed: the works of domestic and foreign authors, including theoretical developments of domestic and foreign scientists, and data from desk research. To assess the scientific infrastructure, desk research was conducted using secondary information and official statistics.

The scientific novelty of the work lies in the attempt to determine the features associated with the systematic approach in the assessment of scientific infrastructure.

The systematic approach was first considered by the Austrian scientist Ludwig von Bertalanffy. Initially, he introduced the concept of "general systems theory". Later, he emphasized that if all elements are interrelated, then they can be combined into one system [2]. This feature is at the heart of the system. That is, if the elements are isolated and do not have specific connections, they cannot be attributed to a particular system.

The issues of infrastructure influence have been dealt with by many scientists from various fields of scientific activity. For example, A.I. Treivish noted its system-forming role, since at each individual level it interacts with various social and economic objects and subjects [1, p. 72].

The literature review is based on a selection of important studies dedicated to the analysis and assessment of scientific infrastructure. Hall, Enriques, Pickford, and Nichols [9] emphasize the importance of a systemic approach to understanding national infrastructure. In a similar vein, Orhean, Giannakou, Antipas, Raikou, and Ramakrishnan [10] investigate the assessment of scientific data search infrastructure, demonstrating its crucial role in facilitating research and data discovery. Albuquerque [11] provides insight into the complex relationship between scientific infrastructure and the process of technological progress, supported by science and technology statistics. Baker and Millerand [12] explore the complexities of designing scientific infrastructure, with special attention to information environments and knowledge domains. De Roure, Jennings, and Shadbolt [13] present the future of electronic science infrastructure, emphasizing the transformative potential of advanced infrastructure in global research endeavors. Collectively, these studies provide a comprehensive understanding of the multifaceted nature of scientific infrastructure. They offer insights into its systemic analysis, data discovery capabilities, impact on technological progress, design peculiarities, and potential for cutting-edge advancements in research infrastructure [14]. These ideas collectively form a solid foundation for further exploration of scientific infrastructure, both on a global scale and in specific contexts.

In general, the scientific infrastructure of a modern system is formed by buildings, structures, equipment, software-hardware environment, and support services that are necessary for the creation (modernization, development) and/or operation of the system or the decommissioning of the system. For example, the scientific infrastructure of a system that is a research and production organization may include a technopark, which consists of technological infrastructure (buildings, structures, and a construction complex). It also consists of engineering infrastructure (communication facilities, including linear-cable facilities). It includes a data center, telecommunications networks, data storage and transmission systems; decision support systems for innovative infrastructure for scientific and technical research and development, etc. [15].

Results and discussion

An essential condition for the successful development of the scientific infrastructure system (SIS) is the effective functioning of all its subsystems and elements. These include scientific potential, innovation entrepreneurship, innovation, and financial infrastructure [16].

The overall state and development of science in Kazakhstan for the period of 2018–2023 are presented in the following table 1.

Table 1 – The main indicators of the state and development of science in Kazakhstan for 2018–2023

Name	Years						Change in 2023 compared to, %	
	2018	2019	2020	2021	2022	2023	2018	2022
1	2	3	4	5	6	7	8	9
Number of organizations conducting R&D, units	384	386	396	438	414	425	110,7	102.7
including								
- government sector	103	100	93	101	106	102	99.0	96.2
- sector of higher professional education (HPE)	95	92	99	95	94	105	110.5	111.7
- business sector	149	158	167	202	179	171	114,8	95.5
- non-profit sector	37	36	37	40	35	47	127.0	134.3
Internal expenditures on R&D, bln. tenge	72.2	82.3	89.0	109,3	121,6	172.6	+ 2.4 times	142.9
as a percentage of GDP	0.12	0.12	0.13	0,13	0.13	0.14	116.7	107.7
Number of employees engaged in R&D, persons:	22378	21843	22665	21617	22456	25473	113.9	113.4
among them								
- research specialists	17454	17124	18228	17092	18014	21534	123.4	119.5
among them								
doctor of sciences	1740	1703	1883	1652	1743	2061	118.4	118.2
doctor of philosophy PhD	856	1045	1755	1952	2462	3458	+ 4 times	140.5
candidates of sciences	4360	4240	4324	3838	3946	4842	111.1	122.7
specialized doctors	336	317	62	55	96	85	25.3	88.5
- technical staff	2836	2734	2686	2824	2783	2446	86.2	87.9
- others	2088	1985	1751	1701	1659	1493	71.5	90.0
Note: Compiled by the authors based on the source [17, 18].								

Accordingly, the increase and decrease in enterprises conducting R&D occurred due to the entrepreneurial sector. This can be seen in figure 1.

It should be noted that in 2023, organizations belonging to the public sector amounted to 102 units, the HPE sector – 105 units, the business sector – 171 units and 45 organizations belong to the non–profit sector. During the analyzed period 2018–2023, the largest number of organizations engaged in R&D falls on the business sector (the share was 40,2% of the total number of organizations in 2023) [17].

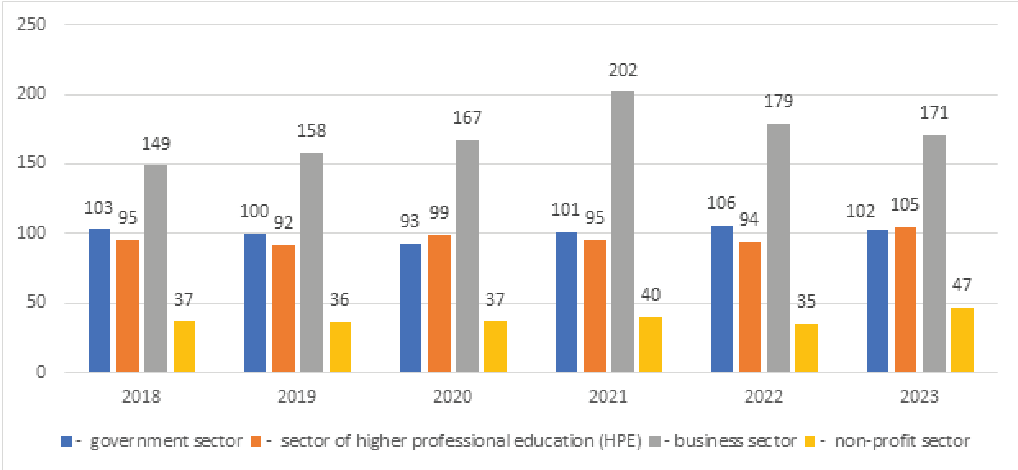

Figure 1 – The number of organizations conducting R&D in Kazakhstan by sectors of activity for the years 2018–2023, units

Note: Compiled by the authors based on the source [19].

The higher professional education sector is next in number, with 105 R&D organizations involved in 2023, which is 24.7% of the total. This sector consists of universities and other higher education institutions, regardless of funding sources or legal status. This also includes research institutes, experimental stations, clinics under their control or associated with them.

The share of the public sector in 2023 was 24%. This sector is represented by ministries and departments. They ensure the governance of the state, as well as meet all the needs of society. This also includes non-profit organizations that are fully or partially funded and controlled by the government. The exception is organizations that belong to higher education. The non–profit sector accounts for the smallest number of organizations engaged in R&D (the share in 2023 is 11.1%).

In the structure of R&D organizations, more than 76% have a private form of ownership. Their number is noticeably growing in absolute numbers. The share of organizations with state and foreign ownership is 19.2 and 4.1%, respectively.

As can be seen from figure 2, in 2023, R&D expenditures conducted in the Republic of Kazakhstan increased significantly from 72224.5 million tenge (2018) to 172585.90 million tenge. But this growth did not affect the science intensity of GDP, which remained at 0.14% in 2023.

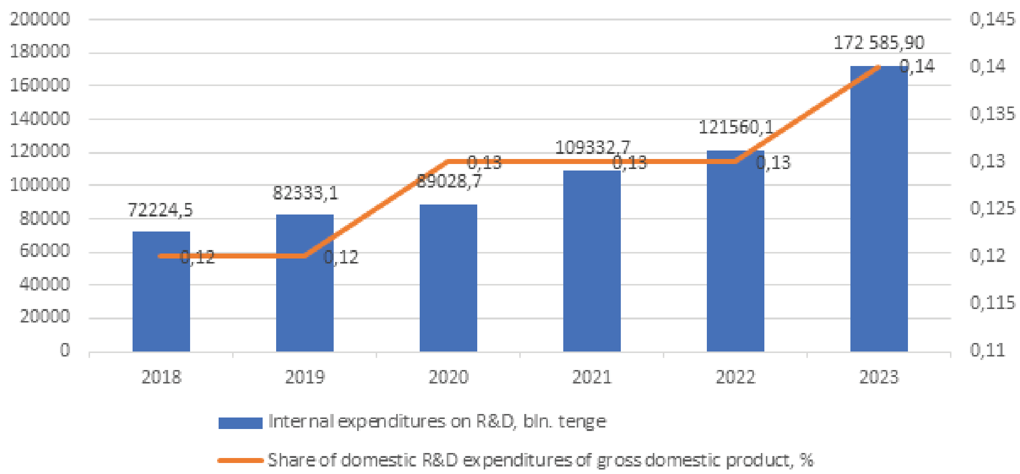

Figure 2 – Internal expenditures on R&D in Kazakhstan for the years 2018–2023

Note: Compiled by the authors based on the source [18, 19].

This is primarily due to the fact that the volume of scientific product produced by scientists – new knowledge remains at a very low level due to its low demand due to the fact that it is not brought to a state where this knowledge can be used in economic activities, in production [17].

In 2023, 82% of research costs will come from new ideas related to people, society, and the environment. Or the basic structure, functions and development of research, so that new ideas can be applied to practical goals and specific tasks, that is, to fundamental and applied research. 18% of the costs were spent on R&D research to create new products, materials, services, processes, equipment or methods for further improvement. In the context of such research, it is difficult to convince entrepreneurs to invest in science, since scientific achievements cannot be used in practice [17, p. 9].

By region, internal R&D expenditures by region for 2018–2023 are shown in figure 3.

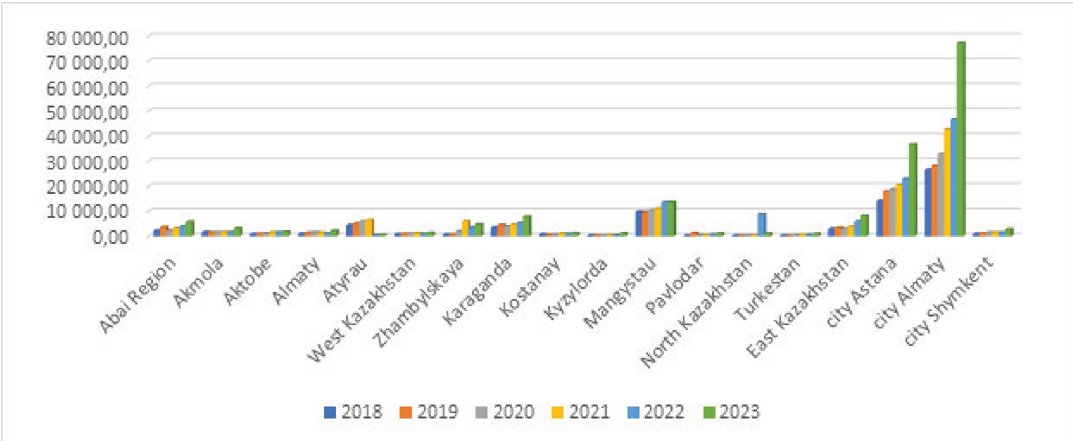

Figure 3 – Internal R&D costs by region for 2018–2023, billion tenge

Note: Compiled by the authors based on the source [18, 19].

As can be seen from figure 3, Astana and Almaty have become the main engines of science in the country, two thirds of all funds intended for R&D have "gone" there. In monetary terms, the cost of science in the main city of the country amounted to 36.7 billion tenge, in the Southern capital – 77.2 billion tenge. Among the regions, only Mangystau (13.6 billion tenge), East Kazakhstan (8.2 billion tenge) and Karaganda (7.8 billion tenge) regions stand out in significant amounts [20].

How internal R&D costs were distributed by branches of science can be judged from the data in table 2.

Table 2 – The volume of internal R&D expenditures by funding sources for the years 2018–2023, billion tenge

Name	Years												Change in 2023 compared to, %	
	2018		2019		2020		2021		2022		2023		2018	2022
Total	72.2 bln	100 %	82.3 bln	100 %	89.0 bln	100 %	109.3 bln	100 %	121.6 bln	100 %	172.6 bln	100 %	+ 2.4 times	142.9
including:														
- natural sciences	21.1	29	21.0	26	25.2	28	31.7	29	36.0	30	58.9	34.1	+ 2.8 times	163.6
engineering developments and technologies	35.6	49	41.8	1	40.9	46	43.7	40	48.9	40	59.5	34.5	121.4	121.7
- medical sciences	2.2	3	2.8	3	2.7	3	8.8	8	7.9	6	8.5	4.9	+ 3.9 times	107.6
-agricultural sciences	8.0	11	10.8	13	12.3	14	14.7	13	14.9	12	20.1	11.6	+2.5 times	134.9
- social sciences	1.6	2	2.3	3	2.7	3	3.0	3	4.6	4	12.7	7.4	+ 7.9 times	+ 2.8 times
- Humanities	3.8	6	3.7	4	5.2	6	7.3	7	9.3	8	12.9	7.5	+ 3.4 times	138.7
Note: Compiled by the authors based on the source [18,19].														

In 2023, engineering developments and technologies account for 34.5% of the share in total R&D costs, this is 59.5 billion tenge, compared to the previous 2022, they increased by 21.7% or 10.6 billion tenge. Natural sciences also have the greatest weight in total costs (34.1%) – this is 58.9 billion tenge, compared to 2022 they increased by 22.9 billion tenge or 63.6%. The lowest costs are for medical sciences (4.9%), social sciences (7.4%) and humanities (7.5%).

In addition to the Research Institute, the scientific potential of the country includes highly qualified specialists who are able to develop ideas that will later be embodied in innovative products and technologies. The innovative economy places high demands on the number and level of qualification of researchers [16, p. 8].

The structure of R&D workers is shown in figure 4.

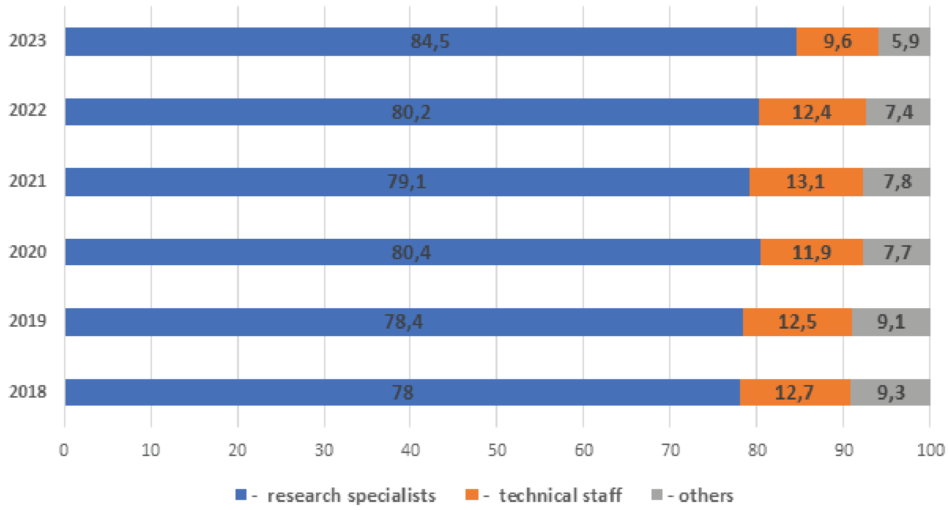

Figure 4 – The structure of employees engaged in R&D for 2018–2023, %

Note: Compiled by the authors based on the source [18, 19].

As can be seen from figure 4, in the structure of employees engaged in R&D, the largest share is accounted for by research specialists (78%-84.5%); technical staff is (11.9%-12.7%); others account for (7.4%-9.3%). According to the results of 2023, compared with 2022: research specialists increased by 19.5% (increased by 3520 people), which amounted to 21 thousand people; technical staff decreased by 337 people, other staff decreased by 166 people. Among the research specialists in 2023: candidates of sciences – 4.8 thousand people; PhD doctors – 3.5 thousand people; doctors of sciences – 2.1 thousand people and doctors in the profile – 85 people. The structure of research specialists for 2018–2023 is shown in figure 5.

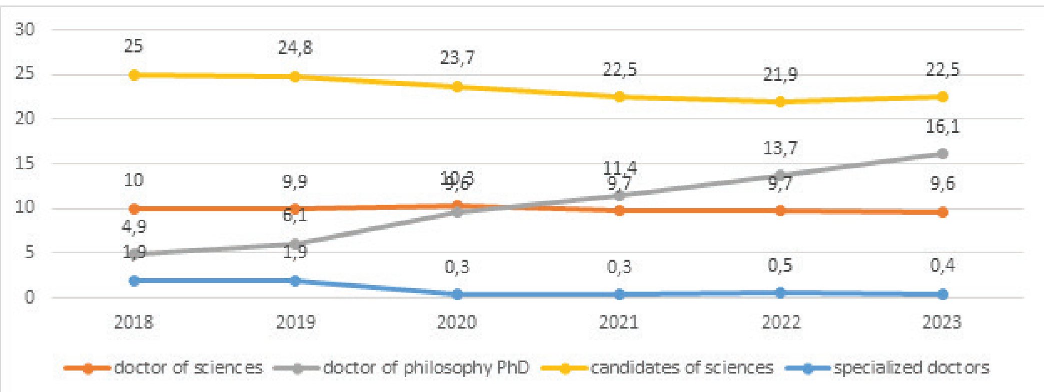

Figure 5 – The structure of research specialists engaged in R&D according to the level of scientific qualification for 2018–2023, in %

Note: Compiled by the authors based on the source [18, 19].

In the structure of research specialists engaged in R&D according to the level of scientific qualification for the analyzed period, the largest share is occupied by candidates of sciences (in 2023 – 22.5%, and in 2018 – 25%), and in comparison with 2022 – 21.9%), while the number of candidates of sciences in 2023 amounted to 4842 people, compared to the previous year 2021 (3946 people) It grew by 896 people or 22.7%. In general, it should be noted that the number of scientists has halved over the past 30 years (since 1991 - from 40.8 thousand people, in 2023 to 25.5 thousand people), since one of the main problems of personnel and scientific potential is the uneven and low level of salaries of scientists (fig.6). As a result, the trend of low attractiveness of the scientific industry persists.

According to global standards, the labor costs of R&D personnel account for the largest part of current costs (figure 6).

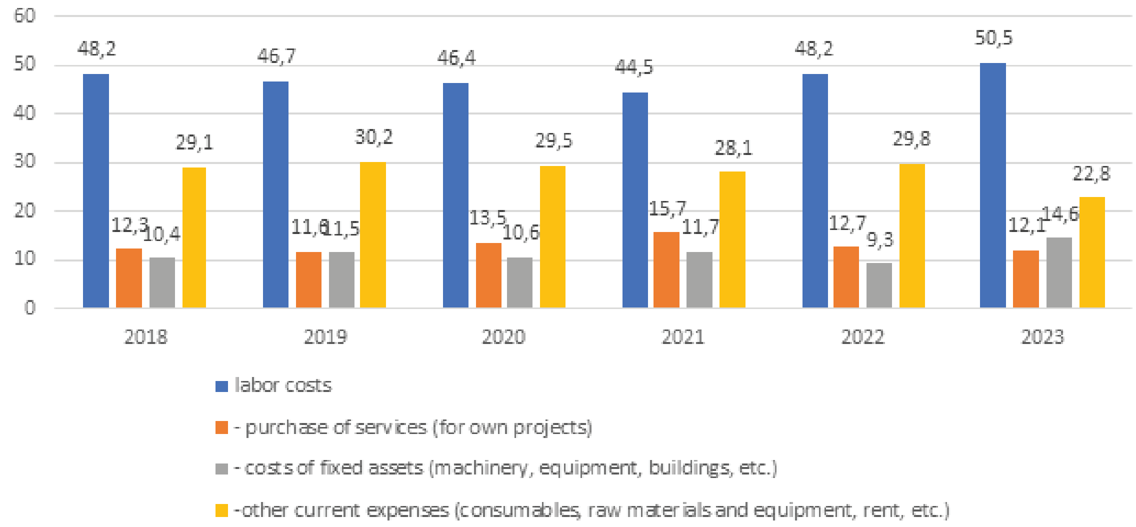

Figure 6 – The structure of internal R&D costs for 2018–2023, %

Note: Compiled by the authors based on the source [18, 19].

In 2023, the largest share in the structure of internal R&D costs was labor costs – 50.5% (87.2 billion tenge); other current costs – 22.8% (39.4 billion tenge); costs of fixed assets – 14.8% (20.9 billion tenge); purchase of services (for own projects) – 12.1% (25.2 billion tenge). In comparison with the previous 2022, labor costs increased by 49% or by 28.7 billion tenge.

If we consider the structure of internal R&D costs in the context of areas of activity in 2023, the following can be noted: out of the total amount of internal R&D costs (172.6 billion tenge):

- the public sector – 49.7 billion tenge – the total structure of internal costs is 28.8%;
- higher professional education sector – 68.3 billion tenge (39.6%);
- business sector – 35.5 billion tenge (20.5%);
- non–profit sector - 19.1 billion tenge (11.1%).

Thus, the analysis of internal R&D expenditures by expenditure shows that it is not possible to achieve a knowledge intensity of GDP of 1%. Due to the fact that the manufacturing sector, considered the main consumer of scientific developments, is significantly inferior to the service sector in terms of GDP formation, therefore, the possibility of shifting the focus of scientific research from the production direction to the service sector should be considered.

The analysis of internal R&D costs (by funding sources) is presented in table 3 (p. 420).

As can be seen from table 3, in 2023, R&D expenditures conducted in the Republic of Kazakhstan increased by 41.9% compared to 2022, or by 51 billion tenge. In 2023, scientific organizations themselves became the main investor in scientific research, accounting for almost 74.4% of costs (128.4 billion tenge), compared with 2022, the share was 68% (82 billion tenge), an increase of 56.6%, or 46.4 billion tenge. In 2023, the share of public funds in total expenditures amounted to 16% (27.6 billion tenge), compared to last year it decreased by 1% or 0.4 billion tenge. The share of foreign investments over the analyzed period remains insignificant, at the level of 1.7%. The share of other sources amounted to 7.9%, increased by 56.3% or 4.9 billion tenge.

Table 3 – The volume of internal R&D expenditures by sources of financing for 2018–2023, billion tenge

Name	Years												Change in 2023 compared to, %	
	2018		2019		2020		2021		2022		2023		2018	2022
Total costs	72.2 bln	100 %	82.3 bln	100 %	89.0 bln	100 %	109.3 bln	100 %	121.6 bln	100 %	172.6 bln	100 %	+ 2,4 times	141,9
including:														
budget funds	32.1	45	36.7	45	46.3	52	64.1	59	28.0	23	27.6	16	86	99
own funds of scientific organizations	34.3	47	37.7	46	35.5	40	36.5	33	82.0	68	128.4	74.4	+ 3.7 times	156.6
foreign investment	1.9	3	3.3	4	2.2	2	2.1	2	2.8	2	2.9	1.7	152.6	103.6
bank loans	0.2	0	0.2	0	0.1	0	0.04	0	0.1	0	0.1	0	50	0
other sources of funding	3.7	5	4.4	5	4.9	6	6.6	6	8.7	7	13.6	7.9	+ 3.7 times	156.3
Note: Compiled by the author based on the source [18, 19].														

One of the indicators that shows the vulnerability of the economy to innovation is considered to be the innovative activity of enterprises. It shows the level of intensity of the actions taken to turn innovations into a completely new or improved product, and this can also apply to technology, organizational and marketing services [18, p. 10].

Innovative activity entails the practical application or utilization of innovative-scientific and intellectual potential in mass production. The goal is to obtain a new product that satisfies consumer demand for competitive products and services.

To assess the innovative activity of enterprises in Kazakhstan for the years 2018–2023, data presented in table 4.

Table 4 – Key Indicators of Innovation Activity of Enterprises in Kazakhstan for the years 2018–2023

Indicators	Year						Change 2023,%	
	2018	2019	2020	2021	2022	2023	2018	2022
Number of enterprises, units	30501	28411	28087	28203	30750	30610	100.4	99.5
of them:								
- having at least one of two types of innovations, units	3230	3206	3236	2960	3390	3592	111,2	106
- having product and process innovations, units	2019	2131	2402	1808	2957	3085	152.8	105.4
Level of activity in the field of innovation, %	10.6	11.3	11,5	10,5	11.0	11.7	110.4	106.4
Production volume innovative products, total, billion tenge	1064.1	1113.6	1715.5	1438.7	1879.1	2399.8	+2,3 times	127.7
Volume of innovative products produced per 1 tenge of costs, tenge	1.23	2.0	2.2	1.8	1.3	1.32	107,3	101.5
Volume of products sold, billion tenge	1019.9	996.9	1664.6	1318.1	1739.8	2381.2	+2,3 times	136.9
Volume of innovative products sold for export, billion tenge	161.7	175.4	308.0	214.5	286.3	420.6	+2,6 times	146.9

Continuation of table 4

Share of innovators products in the total industrial volume. products, %	861.9	545.0	783.2	800.0	1453.3	1820.8	+2.1 times	125.3
Amount of costs for implementing innovations, billion tenge								
including by sources of financing, billion tenge	28.8	37.9	167.4	63.8	101.2	75.5	+2.6 times	74.6
Republican budget	15.8	5,1	14.7	11.5	8.7	14.6	92.4	167.8
Local budget	392.2	448,5	493.1	621.1	693.6	721.1	183.9	104
Own funds	45.6	3.9	11.9	41.1	21.0	5.6	12.3	26.7
Foreign investment	379.5	49.8	96.1	62.5	628.9	1004.2	+2.6 times	159.7
Note: Compiled by the author based on the source [18, 19].								

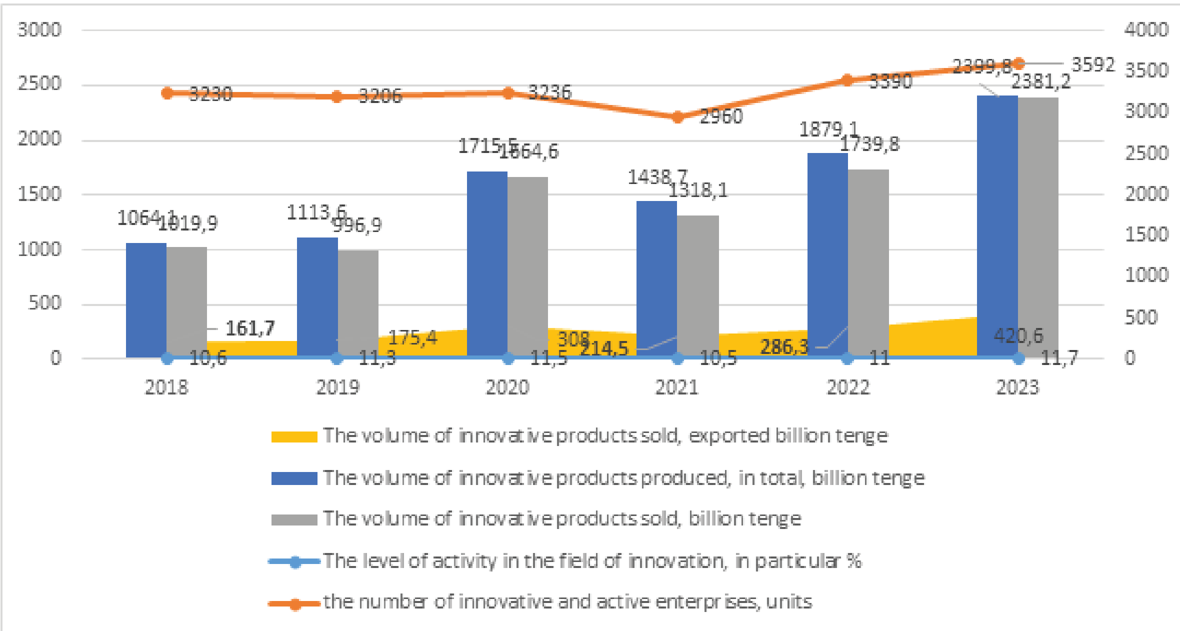

Figure 7 – Key indicators of innovation activity in Kazakhstan for 2018–2023

Note: Compiled by the author based on the source [18, 19].

As can be seen from table 4, in 2023, 3,610 enterprises participated in the innovation activity survey, which is 140 units less than the previous 2022. Of these, 11.7% are innovative and active enterprises, the number of which in 2023 amounted to 3,592 units, which is 6% (202 units) more than in 2022. They produced innovative products in the amount of 2399.8 billion tenge, the volume increased 2.3 times (or by 1335.7 billion tenge) compared to 2018 (it was 1064.1 billion tenge). In relation to 2022, the volume increased by 27.7% (by 520.7 billion tenge).

The total volume of innovative products sold in 2023 amounted to 2381.2 billion tenge, compared to 2022 it increased by 36.9% (by 641.4 billion tenge). The volume of products sold for export in relation to 2022 increased by 46.9% or by 134.3 billion tenge, and in 2023 amounted to 420.6 billion tenge.

The total cost of innovation in 2023 amounted to 1820.8 billion tenge, compared with 2022 it increased by 25.3%, or by 367.5 billion tenge.

In 2023, the purchase of modern machinery, equipment, software and other capital assets accounted for 69.7% of all innovation costs, which amounts to 1269.1 billion tenge.

Conclusion

Based on the conducted analysis, it can be concluded that a systematic approach in evaluating scientific infrastructure is essential to understand which individual elements contribute to development and which act as hindrances. Assessing scientific infrastructure, taking into account the components and interconnections of individual elements within the system, also helps to understand the direction in which scientific development should proceed. If a specific element or the interactions between subsystems are not considered in the evaluation of scientific infrastructure, the resulting picture of scientific functioning will be incomplete. In light of the above, it can be noted that the development of scientific infrastructure is more effective and sustainable when a systematic approach is employed, considering not only strategic issues but also tactical tasks aimed at its development.

Thus, the analysis of Kazakhstan's scientific infrastructure revealed key systemic issues such as:

Low funding levels – 0.13% of GDP.

Decrease in the number of scientists (including young scientists). The low and unstable salary contributed to the reduction in the personnel potential.

Aging research and development (R&D) infrastructure: wear and tear of capital assets is 40%. Wear and tear of laboratory equipment is 50%. Capital expenditures for R&D are 12%.

Insufficient infrastructure for applied research (AR) and technology development (TD). This includes engineering laboratories, experimental platforms, and design bureaus. The ratio of scientists to designers to workers in experimental production is 25:4:1 (compared to the global ratio of 1:2:4).

Weak link between science and production.

Low awareness of companies about the results of R&D and innovation activities of research institutions and universities. For example, according to statistical data, out of 10,337 companies, only 296 collaborated with research institutions, and 320 collaborated with universities in terms of providing scientific information.

It should be noted that systemic measures are currently being taken to develop science. The President of the country, K. Tokayev, stated in a programmatic speech to scientists that science will be oriented towards new production technologies that will make the country competitive [21].

To strengthen the scientific infrastructure and address these systemic issues, a three-pronged approach is envisioned:

- Modernization: Modernizing the existing infrastructure is an urgent necessity. This entails the upgrading of facilities, equipment, and technologies to enhance their efficiency.
- Expansion: To address critical gaps and support new research areas, the creation of new scientific infrastructure is necessary. This includes establishing state-of-the-art laboratories, experimental complexes, and design bureaus.
- Enhanced governance: Improving management methods in scientific organizations and infrastructure is of paramount importance. Enhanced coordination, transparency, and collaboration will foster greater synergy and alignment of actions among stakeholders.

These strategic initiatives promise to expand Kazakhstan's scientific infrastructure, thereby stimulating advancements in various fields. They contribute to socio-economic development, socio-political stability, increased private sector investment in research and development, as well as addressing pressing national and regional issues. In this context, the evolution of Kazakhstan's scientific infrastructure plays a pivotal role in advancing the country toward a more competitive and prosperous future, where science and innovation drive sustainable growth and development.

REFERENCES

1 Станислав О.С. Наука как фактор мягкой силы. Дисс. канд. полит.наук. – Санкт-Петербург, 2016.

2 Ланцов А.Е. Инфраструктура: понятие, виды и значение // Статистика и экономика. – 2013. – № 3. – С. 49–54.

3 Ерашкин Е.А. Теоретические основы формирования и развития инфраструктуры // Современные тенденции в экономике и управлении: новый взгляд. – 2011. – № 12-1. – С. 147–154.

4 Красова Е.В. Научно-исследовательская инфраструктура ДФО в контексте инновационного развития региона: тенденции и проблемы формирования // Университетское управление: практика и анализ. – 2019. – № 23(3). – С. 56–68.

5 Седых И.О., Лапшина Е.Н. Управление созданием инновационной инфраструктуры в современных условиях // Вестник алтайской академии экономики и права. – 2021. – № 1. – С. 85–91.

6 Состав Национальной академии наук Республики Казахстан (НАН РК). URL: https://nauka-nanrk.kz/ru/about/

7 Состав и значение Национальной академии естественных наук (КазНАЕН). URL: https://kaznaen.kz/?page_id=249

8 Состав и задачи Национальной инженерной академии Республики Казахстан (НИА РК). URL: https://neark.kz/ob-akademii/

9 De Roure D., Jennings N. R., Shadbolt N. R. The semantic grid: A future e-science infrastructure // Grid computing: making the global infrastructure a reality. 2003. P. 437–470.

10 Hall J.W. et al. Systems-of-systems analysis of national infrastructure // Proceedings of the Institution of Civil Engineers-Engineering Sustainability. Thomas Telford Ltd. 2013. Vol. 166. No. 5. P. 249–257.

11 Orhean A.I. et al. Evaluation of a scientific data search infrastructure // Concurrency and Computation: Practice and Experience. 2022. T. 34. No. 27. P. 72–61.

12 Albuquerque E.M. Scientific infrastructure and catching-up process: notes about a relationship illustrated by science and technology statistics // Revista brasileira de economia. 2001. T. 55. P. 545–566.

13 Baker K.S., Millerand F. Scientific infrastructure design: Information environments and knowledge provinces // Proceedings of the American Society for Information Science and Technology. 2007. T. 44. No. 1. P. 1-9.

14 Фоминна Ю.А. Исследование теории К. Маркса на основе системного подхода. Часть 1. Теория капитализма // Вестник Омского университета. Серия «Экономика». – 2013. – № 4. – С. 22–27.

15 Сатпаева З.А. Развитие инфраструктурных звеньев инновационной системы Казахстана в условиях становления наукоемкой экономики. – Алматы, 2017. URL: https://www.kaznu.kz/content/files/pages/7928

16 Ибраев А.Ж., Беляева Г.Н., Пономарева Н.И., Козбагарова Г.А. Информационно-аналитический справочник: Наука Казахстана в цифрах за 2017–2021 годы. – Алматы: НЦГНТЭ. – 2022. – 87 с.

17 Шевченко Е. Анализ пробелов в сфере науки, технологий и инноваций (НТИ) в Казахстане // ЕЭК ООН: Усиление инновационной политики для стран СПЕКА в поддержку Повестки дня в области устойчивого развития на период до 2030 года, 2020. URL: https://unece.org/sites/default/files/2021

18 Основные показатели состояния и развития науки. Бюро национальной статистики АСПиР РК. – 2022. URL: stat.gov.kz/industries/social-statistics/ (дата обращения: 16.05.2023)

19 Наука и инновационная деятельность Казахстана / Статистический сборник. – Астана, 2022. – 44 стр. URL: http: //stat.gov.kz (дата обращения: 16.05.2023)

20 Внутренние затраты на НИОКР, 2023. URL: https://energyprom.kz/ ru/articles-ru/ industries-ru/zatraty-na-nauku-v-kazahstane-vyrosli-na-42/

21 Ергалиев К.А. Ключевые приоритеты и задачи науки и высшего образования / Министерство науки и высшего образования Республики Казахстан. – 2022. URL: https://enic-kazakhstan.edu.kz/files/1661575384/ (дата обращения: 16.05.2023)

REFERENCES

1 Stanislav O.S. (2016) Nauka kak faktor mjagkoj sily. Diss. kand. polit.nauk. Sankt-Peterburg. (In Russian).

2 Lancov A.E. (2013) Infrastruktura: ponjatie, vidy i znachenie // Statistika i jekonomika. No. 3. P. 49–54. (In Russian).

3 Erashkin E.A. (2011) Teoreticheskie osnovy formirovanija i razvitija infrastruktury // Sovremennye tendencii v jekonomike i upravlenii: novyj vzgljad. No. 12-1. P. 147–154. (In Russian).

4 Krasova E.V. (2019) Nauchno-issledovatel'skaja infrastruktura DFO v kontekste innovacionnogo razvitija regiona: tendencii i problemy formirovanija // Universitetskoe upravlenie: praktika i analiz. No. 23(3). P. 56–68. (In Russian).

5 Sedyh I.O., Lapshina E.N. (2021) Upravlenie sozdaniem innovacionnoj infrastruktury v sovremennyh uslovijah // Vestnik altajskoj akademii jekonomiki i prava. No. 1. P. 85–91. (In Russian).

6 Sostav Nacional'noj akademii nauk Respubliki Kazahstan (NAN RK). URL: https://nauka-nanrk.kz/ru/about/. (In Russian).

7 Sostav i znachenie Nacional'noj akademii estestvennyh nauk (KazNAEN). URL: https://kaznaen.kz/?page_id=249/ (In Russian).
8 Sostav i zadachi Nacional'noj inzhenernoj akademii Respubliki Kazahstan (NIA RK). URL: https://neark.kz/ob-akademii//. (In Russian).
9 De Roure D., Jennings N. R., Shadbolt N. R. (2003) The semantic grid: A future e-science infrastructure // Grid computing: making the global infrastructure a reality. P. 437–470. (In English).
10 Hall J.W. et al. (2013) Systems-of-systems analysis of national infrastructure // Proceedings of the Institution of Civil Engineers-Engineering Sustainability. Thomas Telford Ltd. Vol. 166. No. 5. P. 249–257. (In English).
11 Orhean A.I. et al. (2022) Evaluation of a scientific data search infrastructure // Concurrency and Computation: Practice and Experience.V. 34. No. 27. P. 72–61. (In English).
12 Albuquerque E.M. (2001) Scientific infrastructure and catching-up process: notes about a relationship illustrated by science and technology statistics // Revista brasileira de economia. V. 55. P. 545–566. (In English).
13 Baker K.S., Millerand F. (2007) Scientific infrastructure design: Information environments and knowledge provinces // Proceedings of the American Society for Information Science and Technology. V. 44. No. 1. P. 1–9. (In English).
14 Fominna Ju.A. (2013) Issledovanie teorii K. Marksa na osnove sistemnogo podhoda. Chast' 1. Teorija kapitalizma // Vestnik Omskogo universiteta. Serija «Jekonomika». No. 4. P. 22–27. (In Russian).
15 Satpaeva Z.A. (2017) Razvitie infrastrukturnyh zven'ev innovacionnoj sistemy Kazahstana v uslovijah stanovlenija naukoemkoj jekonomiki. Almaty. URL: https://www.kaznu.kz/content/files/pages/ 7928. (In Russian).
16 Ibraev A.Zh., Beljaeva G.N., Ponomareva N.I., Kozbagarova G.A. (2022) Informacionno-analiticheskij spravochnik: Nauka Kazahstana v cifrah za 2017–2021 gody. Almaty: NCGNTJe. 87 p. (In Russian).
17 Shevchenko E. (2020) Analiz probelov v sfere nauki, tehnologij i innovacij (NTI) v Kazahstane // EJeK OON: Usilenie innovacionnoj politiki dlja stran SPEKA v podderzhku Povestki dnja v oblasti ustojchivogo razvitija na period do 2030 goda. URL: https://unece.org/sites/default/files/2021/ (In Russian).
18 Osnovnye pokazateli sostojanija i razvitija nauki. Bjuro nacional'noj statistiki ASPiR RK. 2022. URL: stat.gov.kz/industries/social-statistics/ (data obrashhenija: 16.05.2023)/ (In Russian).
19 Nauka i innovacionnaja dejatel'nost' Kazahstana / Statisticheskij sbornik. Astana, 2022. 44 p. URL: http: //stat.gov.kz (data obrashhenija: 16.05.2023). (In Russian).
20 Vnutrennie zatraty na NIOKR, 2023. URL: https://energyprom.kz/ ru/articles-ru/ industries-ru/zatraty-na-nauku-v-kazahstane-vyrosli-na-42// (In Russian).
21 Ergaliev K.A. (2022) Kljuchevye prioritety i zadachi nauki i vysshego obrazovanija / Ministerstvo nauki i vysshego obrazovanija Respubliki Kazahstan. URL: https://enic-kazakhstan.edu.kz/files/1661575384/ (data obrashhenija: 16.05.2023)/ (In Russian).

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СИСТЕМНЫЙ ПОДХОД К АНАЛИЗУ СТРУКТУРЫ НАУЧНОЙ ИНФРАСТРУКТУРЫ КАЗАХСТАНА

Аннотация
В статье используется системный подход к изучению структуры научной инфраструктуры Казахстана, подчеркивается ее роль как гармоничной сети организаций, занимающихся развитием предпринимательства

в сфере науки и техники. Основная цель состоит в том, чтобы всесторонне оценить научную инфраструктуру Казахстана, охватывающую ее составляющие элементы, общее состояние науки в стране, ее научный, научно-технический и человеческий потенциал. Кроме того, в статье проводится тщательное изучение условий в различных научных областях. Посредством этого анализа в статье выявляется сложная сеть связей, которые придают научной инфраструктуре системные атрибуты, позволяющие всесторонне понять их разнообразие, качество и различные роли в ее развитии. Примечательно, что автор подчеркивает ключевую роль, которую играет государство в формировании и развитии научной инфраструктуры, поскольку оно обладает потенциалом для объединения основных ресурсов, необходимых для ее эффективного функционирования. Это необходимо для внедрения системных инноваций в экономике, тем самым стимулируя хозяйствующие субъекты к новым достижениям. Кроме того, статья предлагает систематическое исследование научной инфраструктуры Казахстана, подчеркивая ее значение как фактора, способствующего инновациям и коммерциализации научно-технических исследований.

Ключевые слова: инфраструктура, научная инфраструктура, инновация, исследователи, внутренние затраты, финансирование, технологическое развитие, человеческий потенциал.

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ҚАЗАҚСТАННЫҢ ҒЫЛЫМИ ИНФРАҚҰРЫЛЫМЫНЫҢ ҚҰРЫЛЫСЫН ТАЛДАУДЫҢ ЖҮЙЕЛІК ТӘСІЛІ

Аңдатпа

Мақалада Қазақстанның ғылыми инфрақұрылымының құрылысын зерттеуге жүйелі көзқарас қолданылады, оның ғылым мен техника саласындағы кәсіпкерлікті дамытумен айналысатын ұйымдардың үйлесімді желісі ретіндегі рөлі аталып ұсынылған. Негізгі мақсат – оның құрамдас элементтерін, елдегі ғылымның жалпы жай-күйін, оның ғылыми, ғылыми-техникалық және адами әлеуетін қамтитын Қазақстанның ғылыми инфрақұрылымын жан-жақты бағалау. Сонымен қатар мақалада әртүрлі ғылыми салалардағы жағдайларды мұқият зерттеу жүргізіледі. Осы талдау арқылы мақалада ғылыми инфрақұрылымға олардың әртүрлілігін, сапасын және оның дамуындағы әртүрлі рөлдерді жан-жақты түсінуге мүмкіндік беретін жүйелік атрибуттар беретін байланыстардың күрделі желісі анықталады. Бір қызығы, автор мемлекеттің ғылыми инфрақұрылымды қалыптастыру мен дамытудағы негізгі рөлін атап өтеді, өйткені оның тиімді жұмыс істеуі үшін қажетті негізгі ресурстарды біріктіру мүмкіндігі бар. Бұл экономикада жүйелі инновацияларды енгізу үшін қажет, осылайша шаруашылық жүргізуші субъектілерді жаңа жетістіктерге ынталандырады. Сонымен қатар бұл мақалада Қазақстанның ғылыми инфрақұрылымын жүйелі зерттеу ұсынылады, оның ғылыми-техникалық зерттеулерді инновациялауға және коммерцияландыруға ықпал ететін фактор ретіндегі маңыздылығын аталды.

Тірек сөздер: инфрақұрылым, ғылыми инфрақұрылым, инновация, зерттеушілер, ішкі шығындар, қаржыландыру, коммерцияландыру, технологиялық даму, адами әлеует.