

Analysis, evaluation and justification of labor productivity growth in construction

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Abstract: Nowadays, the construction industry demonstrates high positive dynamics. However, its development is constrained by a number of factors, the most persistent being the lack of labor productivity growth in the construction sector. To determine the current value of productivity, the factors influencing it, and to find ways to increase it, methods were used to determine its value, taking into account the influence of one or more factors over the base period, as well as probabilistic models to determine its value in the future after the base period. As a result of the conducted research, it was possible to establish that such labor productivity values are a consequence of the fact that construction organizations do not implement measures to improve organizational and technological solutions aimed at modernizing construction production, as well as the emergence of additional problems in construction production at the present stage. The research shows that active growth of labor productivity indicators is achieved by taking into account large-scale state support by implementing a set of current and strategic measures. Grouped current measures represent an evolutionary path of labor productivity growth, while strategic measures reflect a fundamentally new approach to the development of the entire construction production system.

Keywords: Construction market, Construction organizations, Current activities, Global challenges, Influencing factors, Labor productivity in construction, Organizational and technical level, Reserves for labor productivity growth, Strategic activities.

1. Introduction

Construction as a branch of material production is currently one of the main driving forces of the country's market economy. The direct contribution of the housing construction sector alone to GDP is about 1.7%. The industry carries out a colossal volume of construction and installation works. At the same time, a constant growth in investments is clearly visible. For example, according to Rosstat (Federal State Statistics Service of Russia), in 2022, their value amounted to 13.1 trillion rubles, and in 2023, 15.1 trillion rubles. Every year, a huge number of buildings and structures are commissioned, reconstructed, and overhauled. In 2022, housing commissioning reached a record 102.6 million square meters of living space, and in 2023, this figure was 110.4 million square meters of living space [1]. In general, the construction industry demonstrates high positive dynamics and has a fairly solid basis for promising intensive growth.

But at the same time, the development of the construction industry is constrained by a number of factors that significantly limit the production activities of construction organizations. Among these negatively influencing factors, the persistent lack of labor productivity growth in construction production stands out with remarkable consistency year after year. And especially at the present time, when so many houses are being built, the issues of increasing production in the construction industry should be addressed at the state level.

Traditionally, production is determined in two ways [2]. The first is based on its definition of the ratio of the volume of work to labor costs, while the second defines labor costs, which are determined in the opposite way. The output indicator is expressed in natural units of measurement (t, sq.m., cu.m., lin. m.) and indicates the quantity of manufactured products, the volume of work performed, but does not reflect its quality.

The second level of labor evaluation covers the activities of the entire construction organization and is measured by cost indicators.

To determine the rate of change (increase, decrease) in labor productivity for the period under consideration compared to the base period, the labor productivity index is used, which primarily characterizes the degree of activity in identifying and using labor reserves.

The labor efficiency parameter in construction indicates the dynamics of the productivity indicator. The main, additional, and intermediate indicators are used to determine the level of efficiency in the industry.

- Basic parameters. The amount of work performed by one person per year, day, and hour is taken into account. The amount of work performed per year can be calculated as the cost.
- Additional parameters. Labor costs are defined as the ratio of the time spent on a job to its quantity, or as the number of products created per unit of time.
- Intermediate parameters. They also take into account the labor costs for performing one unit of work or productivity for one linear meter.

The value of this indicator increased in 2008 but decreased in 2009–2010. Then, the indicator increased in 2011–2012, and its value decreased significantly the following year. A completely similar picture was demonstrated in the period from 2016 to 2019 (Table 1) [3–5].

Table 1.
Change in the labor productivity index (LPI) in construction.

Indicator	Index value by year			
	2016	2017	2018	2019
LPI, % (Labor productivity)	101.4	97.3	100.7	98.7

According to Rosstat, in 2022, labor productivity growth in construction amounted to 1.8% compared to the previous year. However, labor productivity in construction as a whole lags significantly behind the Russian average, which is determined by industry as the ratio of added value to the average annual number of workers employed in a given industry. For example, in 2010, the Russian average and labor productivity levels in construction amounted to 527 thousand rubles and 481.64 thousand rubles, respectively, and in 2019, 1,337 thousand rubles and 800.02 thousand rubles, respectively [5].

The works of many authors indicate that the main factors in construction are technological, engineering, social, economic, and natural factors that affect labor efficiency in the industry [6–11]. Some authors identify and consider the impact on labor productivity of only the main factors that can be controlled using digital modeling of the production process, with an indication of the maximum limits of the labor productivity assessment indicator. In other words, the emphasis is placed on stricter planning and technological disciplines. Some authors see the solution to the problem of increasing labor productivity, for example, only in increasing industrialization and automation of construction production or in changing the system of training and recruiting only professional personnel. Of course, the optimized selection of workers in the team significantly improves labor productivity. However, the potential for improving the performance indicator changes over time due to scientific and technological progress. This potential is very significant, including reducing the loss of working time during the day and the use of modern technologies and methods of work, so you should always evaluate the effectiveness of work and the effectiveness of measures taken.

2. Materials and Methods

In order to identify the root causes of the resulting performance indicator and determine its increase, it is necessary to take into account how much the described parameters affect efficiency and how much they can change [12-14]. A study of a significant number of factors for different types of work performed by the authors in various construction companies suggests that the quality level of work performed is largely a function of parameters such as the total number of employees, the number of jobs performed, downtime during the day or for several days, employees solving non-production tasks, lack of mechanization of some jobs, low qualifications of employees, the specialization of workers, absence due to illness, and lack of motivation, taking into account the payment systems used. The remaining indicators generally have a less significant impact, about 20%.

To assess the level of labor productivity in the lower divisions of construction organizations, it is reasonable to use:

- A single-factor method, which involves determining the level of natural output at a specific point in time before the end of the base period.
- A multi-factor method, which allows assessing the level of natural output for the entire base period.
- A predictable method, which ensures the determination of the level of labor productivity for the post-base period.

The use of the above methods for assessing and forecasting changes in natural output in lower divisions ensures a fairly objective and accurate reflection of the emerging conditions of work production due to the high degree of homogeneity of construction products [15].

A different matter is the assessment of labor productivity across a construction organization as a whole, particularly when it produces a wide range of construction products. In addition, it is necessary to take into account a number of new factors. For example, shifting the volumes of certain works from the construction site to industrial production (such as prefabricated or modular construction methods) significantly reduces the number and complexity of technological operations in construction production and, therefore, significantly increases the productivity of construction work. Therefore, in plans for the use of labor resources, it is necessary to correctly determine the ratio between an increase in labor efficiency and an increase in wages, while, first of all, it is necessary to try to increase labor efficiency.

Therefore, when determining the scope of work and creating mathematical models to increase the volume of products, the following groups of indicators should be considered, as they determine efficiency:

- The proportion of work performed independently and the amount of work subcontracted;
- The share of individual works – zero cycle work, loading and unloading, installation of coatings;
- Fixed and current assets – the cost of equipment, the total cost of machinery, the availability of own working capital;
- Labor force utilization indicators – productivity coefficient, staff turnover, wage share, mechanized labor utilization rate, total number of employees, proportion of workers for construction, installation, and ancillary work, wage level;
- The cost of work – the cost of materials, the use of the flow method;
- Cost management – labor costs not related to production, loss of time during work, etc.

As a rule, for a general construction organization, models of the influence of factors on the output of one worker, in addition to other factors, necessarily include indicators of the volume of work by own forces and average wages (positive factors), as well as staff turnover and labor intensity coefficient (negative factors) [15].

The reserves for labor productivity growth in construction are quite significant. According to research by the Russian Academy of Sciences, the indicator of labor efficiency in the industry in our

country, which is the ratio of gross domestic product (GDP) to the number of construction workers, is two times less than the same indicator in the United States [16].

3. Results and Discussions

The most significant entities in the industry are construction companies with qualified employees, construction machinery, and vehicles. Analysis of the construction industry development shows that the current construction market began to emerge from the moment of the liberalization of the country's economy in 1991, during the difficult conditions of the collapse of the entire management system of that time. Construction companies were forced to develop strategic and current plans, in particular, to compile a list of completed contract work, find funds, and purchase machinery and equipment. As a result, competition was formed; some players remained in the construction sector, some significantly reduced the volume of work performed, while others went bankrupt.

The transition to new forms of management and property reform in most construction organizations was carried out without additional measures to improve the organizational and technical level of production, update funds, maintain specialization, and increase the mobility of construction units. Wages were not actually linked to the performance indicators of construction production. Progressive methods of work production and forms of labor organization were extremely poorly used. Such important documents as the COP (Construction Organization Project) and the WPP (Work Production Project) began to lose their significance. For example, the WPP was often limited to developing a simplified general construction plan, coordinating the allocation of construction equipment, and obtaining approvals and permits from supervisory authorities. During this period, the structure of labor resources and the work schedule changed significantly. A number of skilled workers and engineering and technical personnel left the industry, and the number of construction laboratories and quality control departments decreased by more than 60%. Dozens of serious accidents involving buildings and structures were registered annually, including those with fatalities and injuries. For example, in 1999, the State Architectural and Construction Supervision Service issued about 70 thousand orders, and work was stopped at 12 thousand construction sites. In addition, the large fleet of construction machinery was renewed annually by 1-2%, while the norm was 8-12%. The fleet of machinery quickly aged, and new equipment was acquired in small quantities. As a result, there was a sharp decline in labor productivity, and the foundation not established at that time continues to have an impact to this day. In 2023, the Russian construction market included 395 thousand construction organizations. By this time, the total revenue of organizations in the construction industry and housing and communal services amounted to 20.7% of the total revenue for all types of economic activity. The volume of work performed by construction organizations has been steadily growing from year to year. At the same time, the structure of work, as a rule, was relatively stable. Thus, the performance of basic construction and installation works on the construction of buildings and structures accounted for about 80-85% of the total volume, and the organization and preparation of the construction site - 6.5-7.0%. At the same time, the development of the production activities of construction organizations was and continues to be significantly negatively affected by such factors as the high cost of materials - 47%, lack of skilled workers - 33%, high taxes - 33%, competition from other firms - 22%, high percentage of commercial credit - 16%, lack of orders - 16%, weather conditions - 12%, lack of financial resources - 11% [1].

The construction industry, like other sectors of the economy, has faced global problems and challenges that have significantly affected and worsened its microclimate - the collapse of oil prices in 2014-2016, the spread of the COVID-19 coronavirus infection in 2020-2021, and the introduction of numerous packages of anti-Russian sanctions. As a result, the Russian currency has weakened twofold, import purchases of materials, products, and equipment have significantly risen in price, and in some cases, have stopped altogether. The financial situation of construction organizations has worsened, and their investment activity has decreased [17-19].

To stabilize the construction sector in the current economic situation, government agencies have implemented a set of economic measures. In the first half of 2020, some fines for customers were lifted,

support for developers was implemented through subsidizing loan rates of up to 5.5% as part of project financing, and an affordable mortgage program with an interest rate of 6.55% was introduced for buyers of new buildings. This facilitated the introduction of new residential facilities to the market and ensured demand through the government's purchase of unsold apartments from developers. In 2022, it was allowed to make changes to design documentation in a simplified manner to replace imported materials and equipment, the system of preferential mortgages was expanded, administrative barriers in resolving land and legal issues were simplified, etc.

During this entire period of the construction market's formation, the problems of increasing labor productivity were not among the primary ones, especially since the market was flooded with a huge flow of migrants from Central Asian countries and Ukraine. However, this does not mean that labor productivity was beyond the attention of the industry's engineering and technical personnel. In the overwhelming majority of construction organizations, the implementation of measures to identify and manage reserves for increasing labor productivity has continued without interruption.

A significant role in the need for a radical increase in labor productivity in construction was played by the order of the Government of the Russian Federation dated October 31, 2022, No. 3268-r, "On Approval of the Strategy for the Development of the Construction Industry and Housing and Communal Services of the Russian Federation for the Period up to 2030 with a Forecast up to 2035." In particular, this document provides for basic and risky options for increasing the number of people employed in the industry and labor productivity in construction (Table 2).

The results of the study and the generalization of the extensive domestic experience allow us to conclude that active growth of labor productivity indicators is achieved by taking into account large-scale state support through the implementation of, first of all, a set of current and strategic measures [20, 21].

Current measures for increasing labor productivity represent an evolutionary path to improving their indicators. It is advisable to organize these measures into four groups:

Table 2.

Options for growth in the number of people employed in the industry and labor productivity in construction.

Indicators	The value of indicators by year			
	2021	2024	2030	2035
Number of people in the construction industry, thousand people				
Scenarios:				
<i>baseline</i>				
	6496	6528	6841	7294
<i>risk</i>	-	6196	6517	6890
Labor productivity, %				
Scenarios:				
<i>baseline</i>	100	103	122	130
<i>risk</i>	-	101	112	117

Group 1 "Technical and technological measures" covers the adaptation of modern production technologies, the mechanization and automation of operations, the use of high-quality materials, etc.

Group 2 "Organizational measures" - rational organization of labor, reduction of whole-shift and intra-shift downtime, timely provision of materials, regular certification, and arrangement of workplaces, etc.

Group 3 "Socio-economic measures" covers improving the skills of workers, optimizing working and living conditions, strengthening material and non-material incentives, as well as expanding social guarantees for employees, and more.

Group 4 "Structural and managerial measures" - creation of adaptive organizational structures, introduction of forms of specialization, cooperation, and combination of production, formation of a management system, effective personnel management, etc.

Strategic measures for increasing labor productivity reflect a revolutionary path of a fundamentally new approach. Such measures, as applied to housing construction, include at least six focus areas.

3.1. Focus Area 1. Transition To Highly Industrialized Standardized Systems of Buildings and Structures

The systems under consideration are mainly modular structures assembled from pre-manufactured large blocks in factories in a state of either complete or almost complete accomplishment. These elements already have an interior finish and are equipped with the necessary devices and equipment, including plumbing and household appliances. The size of such modular units is determined by their manufacturing capabilities and the degree of automation of construction processes. Currently, large-scale blocks are products of the MonArch Group of Companies, weighing up to 65 tons. At the same time, as a rule, a large-scale block is designed to accommodate an apartment with a total area of 100–120 sq.m. The degree of readiness of such a block has been brought to 98% (Fig. 1).

The multi-object, multi-level flexible panel housing system (FPHS), developed by TsNIEPzhilishcha, is promising. It allows for changing the facades and appearance of large-panel buildings and creating virtually any layout structure of apartments with variable room layout solutions. Additionally, this system provides several new engineering and technical solutions for the operation of the building, its safety, and security. Therefore, the most important goal in the development of the construction industry is the deep modernization of existing production facilities and the creation of new industrial complexes and factories for the large-scale production of modular concrete products, structural elements, and a variety of innovative building materials. This will enable the production of ready-made building components using advanced technologies on production lines. The increased use of modular components in the process of technical preparation at construction sites helps to accelerate project implementation and improve the quality of construction work. The intensification of housing and civil facilities construction is becoming a key factor in achieving national goals to improve housing conditions and urban infrastructure quality.

Consequently, the implementation of this key project helps to optimize the process by transferring significant amounts of construction and installation work from the construction site to industrial production facilities.



Figure 1.
Large-scale volumetric block with advanced prefabrication.

3.2. Focus Area 2. Expanding the Use of Industrial-Mobile Methods and Forms of Construction of Buildings and Structures

Over time, construction companies have significantly increased their mobility, which has allowed them to operate successfully in different regions and conditions. Mobile teams are actively involved not only in the construction of new facilities but also in managing peak load periods, often at the initial stages of projects. The mobility of construction companies is increasing especially rapidly in hard-to-reach areas, including the Far North, the Arctic, Siberia, and the Far East. Modern mobile units are now also actively involved in the construction of large-scale facilities near major cities and in the European part of the country, such as housing complexes and production units. This trend in mobile construction contributes to a new quality in approaches to the design and construction of architectural objects.

Being located at considerable distances from the main bases and production facilities of the construction industry and often faced with extreme climatic conditions, mobile construction teams must ensure efficiency with minimal time and labor costs. Therefore, the principle of centralization of production processes within industrial plants, subsequent transportation, and installation on construction sites is the key to construction operations. This leads to a reduction in the volume of construction and installation work on site to 10-15% of the total volume (see Fig. 2).

The synergy of industrial construction technologies and flexible labor management methods ensures the sustainable development of the construction sector, minimizing dependence on regional characteristics and the impact of natural conditions [17, 20].



Figure 2.
Installation of a large-scale prefabricated volumetric block.

It should be noted that the duration of construction using the specified methods is reduced several times. At the same time, further development of this technology will soon allow for near-complete automation of the entire construction process for buildings and structures (Fig. 3) [21].

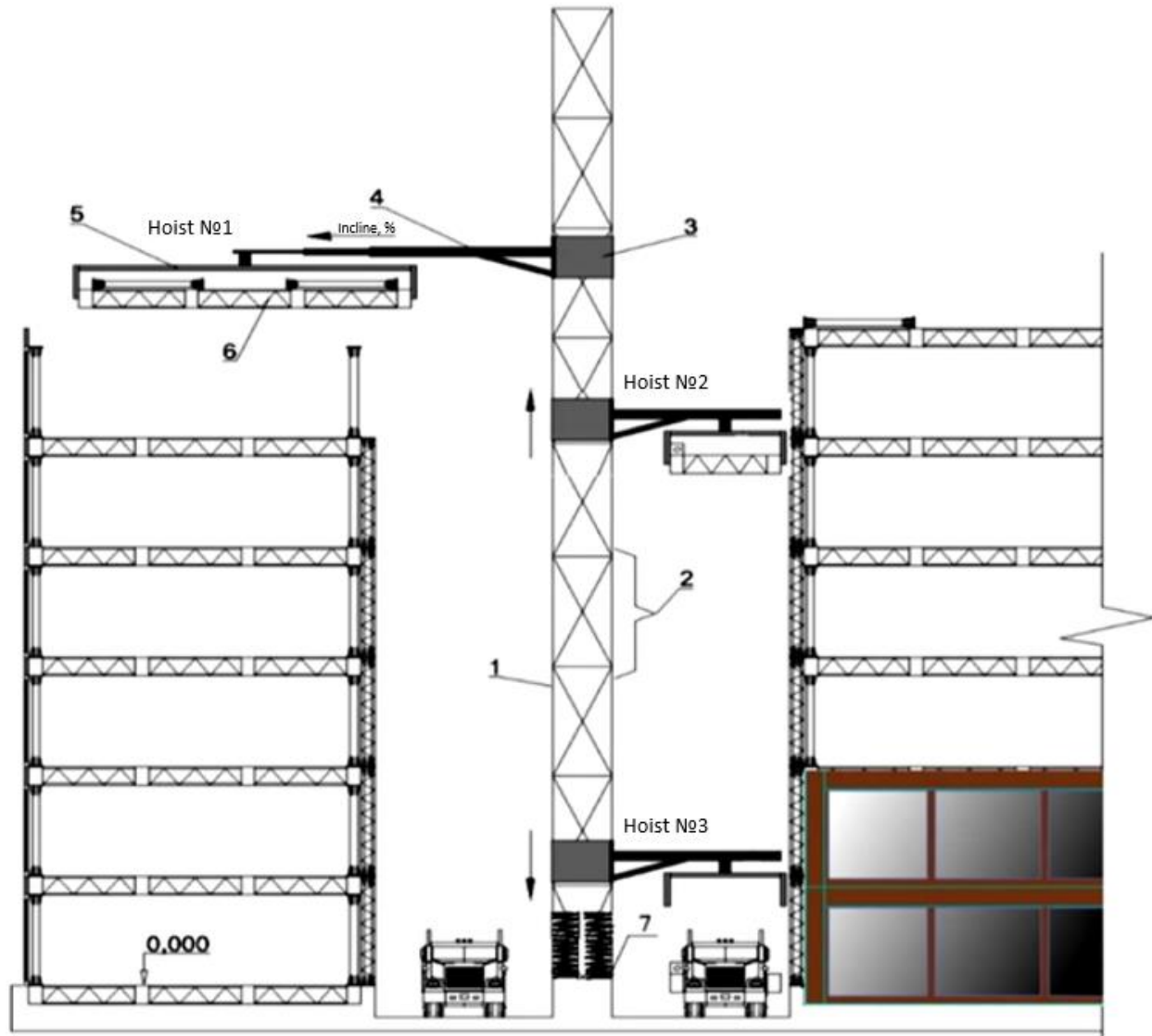


Figure 3.

Scheme of installation of volumetric blocks by robotic lift.

Note: 1. Mast assembly robot, 2. Mast section, 3. Mobile trolley, 4. Telescopic platform, 5. Gripper, 6. Volume block, 7. Assembly springs.

3.3. Focus Area 3. Concentration of Financial, Labor and Material Resources in Construction Production

According to Rosstat, over 400 thousand residential and non-residential facilities have been commissioned annually in recent years. For example, in 2022, the number of commissioned facilities amounted to 434.1 thousand units, and taking into account transport construction facilities, the total number of such facilities was at least 520 thousand units. At the same time, in the construction industry, which includes construction itself, production of building materials, logistics, maintenance, and repair of equipment and transport, etc., the number of employees is approximately 6.5 million people. Of these, about 2.5 million work in the construction sub-sector itself. Consequently, an average of 4.8 people worked at each facility, including machine operators and drivers. Such low rates of utilization of labor and material and technical resources are the main reasons for exceeding the standard (directive) duration of construction and the accumulation of unfinished construction. A similar situation occurs

with the financing of objects, where only 3-5% of the cost of construction and assembly work is allocated and spent in the first year of construction. Even at this initial stage, this already predetermines slow progress and irrecoverable time losses.

Thus, an appropriate balance is required between the number of objects being erected and the number of workers, which can be established and maintained for each object in accordance with the design decisions of the COP.

3.4. Focus Area 4. Realization of Human Resource Potential

The construction industry has the highest personnel shortage, which in recent years has fluctuated between 1.1 and 1.5 million people. The number of vacancies at construction sites has increased by 31% compared to 2022. There is a need for concrete workers, reinforcement workers, monolithic workers (up to 40%), finishers (up to 20%), welders, bricklayers (up to 12%), etc. In some regions, the shortage of workers is up to 50%. Attracting foreign labor only partially solves this problem. According to the Russian Ministry of Construction, about 800 thousand migrants worked at construction sites in the country. Unfortunately, most migrants from Central Asia cannot correctly read technical documentation, comply with technological process regulations, or work with modern equipment. In addition, the construction industry is characterized by high staff turnover (Table 3).

Table 3.

Personnel movement in the construction industry.

Action	Number of personnel by year					
	2015	2017	2018	2019	2020	2021
Hired, %	43.8	50.5	56.3	57.8	52.9	63.3
Left, %	57.3	56.8	59.8	64.9	56.3	65.3

Currently, a system of relevant measures is being implemented in this focus area, including the introduction of patents for foreign workers, training of personnel in 1,260 colleges and 20 universities in the country, the development of professional standards for engineering and technical workers, and qualification standards, increasing material and moral incentives, etc.

3.5. Focus Area 5. Integration of Information Modeling Technologies into the Management System of Investment and Construction Projects

Transfer of the entire system of manual management of construction and investment projects to information modeling technologies through the development and implementation of:

- Three-dimensional modeling with full information at the design, construction and operation stages;
- A single digital construction platform, including legislative, legal, regulatory, technical and methodological foundations for managing the life cycle of capital construction projects;
- A high level of interaction between participants in the construction of the facility as a result of its implementation.

The creation of virtual prototypes of buildings, their structures, and elements provides the opportunity for real influence on the entire process of forming finished construction products, which significantly accelerates the development of projects, reduces the costs of producing classic models, decreases the time required for making engineering decisions, and simplifies procedures for coordinating and examining design documentation.

The virtual reality system is connected to computer-aided design (CAD) tools, allowing for rapid project modifications, visualization of their impact on the virtual prototype, and the avoidance of costly errors. The high efficiency of the virtual reality system in developing organizational and technological documentation and making operational management decisions should be especially emphasized.

3.6. Focus Area 6. Elimination of Physiological Discomfort of Workers in the Construction Industry.

The Russian Federation is a northern country. Almost two-thirds of its territory is located in the permafrost zone with severe climatic conditions, and the regions of the Far North and the Arctic are generally characterized by an extreme climate. Natural and climatic conditions, the duration of stay on shift (expedition), the degree of labor intensity, and other factors in the development of such territories significantly affect the production and physiological capabilities of workers. At the same time, without knowledge of the medical and biological limitations of labor activity, it is impossible to competently and objectively plan and manage production and quality of work.

Domestic science considers three forms of rehabilitation of the human body: adaptation (reaction norm), adaptive norm (acclimatization), and pathology (disintegration of the main vital processes), expressing the restructuring and adaptation of the body to environmental conditions. Ongoing study of this practice already today allows us to establish worker health requirements, develop rational work and rest regimes, and apply effective methods and forms of work organization. At the same time, the task of selecting not only a worker as a qualified and healthy specialist but also the formation of links, brigades, and groups with a high level of mutual support from workers is becoming increasingly urgent [17, 19].

4. Conclusion

The construction market was formed without the proper implementation of comprehensive measures to improve the organizational and technical level of production, update fixed assets, maintain specialization, and increase the mobility of construction units. As a result, this led to a sharp decline in labor productivity in construction. Subsequently, the construction industry, like other sectors of the economy, faced global problems and challenges, which worsened the financial situation of construction organizations, reduced their investment activity, and did not allow for a large-scale solution to the problem of increasing labor productivity.

A significant role in the need for a radical increase in labor productivity in construction belongs to the order of the Government of the Russian Federation of October 31, 2022, No. 3268-r, which considers this problem a priority state task. The document provides a strategy for the development of the construction industry and sets benchmarks for labor productivity growth until 2035.

The generalization of vast domestic experience and the results of research by many specialists make it possible to substantiate and formulate the main directions for the growth of labor productivity in construction production as a comprehensive combination of current and strategic measures, the basis of which are modern achievements of scientific and technological progress.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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