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Lean production in the context of housing and civil engineering in Arctic

Producción Lean en el contexto de la vivienda y la ingeniería civil en el Ártico

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Content

ABSTRACT:

Recently, the Arctic region is the object of increased interest of the countries-world leaders. Russia is among these countries. So, the development strategy of the Arctic zone of the Russian Federation and national security for the period up to 2020 was approved by the President. In this strategy, the socio-economic development of the region in terms of improving the quality of life, expressed in the implementation of housing and civil engineering plays a significant role. The aim of the research is to identify effective organization model of construction in the Arctic zone of the Russian Federation. Lean construction as a kind of derivative of lean production and as a dynamically developing methodology is considered. Features of housing and civil engineering in the Arctic zone are analyzed. The conclusion about the correspondence of the characteristic features of lean construction to the necessary requirements for the construction of different infrastructure objects in the Arctic zone is made. Thus, the concept of lean production in terms of housing and civil engineering could be an effective development strategy for the Arctic countries.

key words lean construction, Arctic zone of the Russian Federation, the last planner system, housing and civil engineering.

RESUMEN:

Recientemente, la región del Ártico es el objeto de mayor interés de los países líderes del mundo. Rusia se encuentra entre estos países. Así, la estrategia de desarrollo de la zona del Ártico de la Federación de rusia y de seguridad nacional para el período hasta el año 2020 fue aprobada por el Presidente. En esta estrategia, el desarrollo socio-económico de la región en términos de mejora de la calidad de vida, expresada en la implementación de la vivienda y de ingeniería civil juega un papel importante. El objetivo de la investigación es identificar efectivo el modelo de organización de la construcción en la zona del Ártico de la Federación de rusia. Lean construction como una especie de derivado de la producción ajustada, y como una forma dinámica el desarrollo de la metodología se considera. Características de la vivienda y de la ingeniería civil en el Ártico de la zona analizada. La conclusión acerca de la correspondencia de los rasgos característicos de la construcción eficiente a los requerimientos necesarios para la construcción de diferentes infraestructuras de objetos en la zona del Ártico está hecho. Por lo tanto, el concepto de lean de producción en términos de vivienda y de ingeniería civil podría ser una efectiva estrategia de desarrollo para los países del Ártico.

Palabras clave lean construction, Ártico zona de la

	Federación de Rusia, el último planificador del sistema, la vivienda y la ingeniería civil.

1. Introduction

Recently, the world economy development is characterized by extremely unstable phenomena. In conditions of high global competition, a well-built state program of development and ability to respond quickly to the changes in the external environment come to the fore. So, in recent years, the Arctic region is increasingly attracting the interests of the countries that are world leaders. About 80% of undiscovered oil and gas reserves are hidden in the Arctic shelf. Taking into account the trend of melting ice and high mineral potential, the region is very promising.

The Arctic is becoming a strategic vector of Russia's development, both from the point of view of strengthening positions on the international arena and ensure the national interests. In the future, this region will be able to contribute to the economic growth of the country. In February 2013, the development strategy of the Arctic zone of the Russian Federation and national security for the period up to 2020 was approved by the President. Plans of expanding Russia's military presence in the Arctic is an essential part of this document. But also the issues of ensuring sustainable socio-economic development of the Arctic zone of Russia occupy a significant place. The construction industry is a driver of economic growth. Therefore, the object of the research is the housing and civil engineering in the Arctic part of Russia.

The region is characterized by a number of features that are associated with extreme natural conditions. At the same time, the domestic construction industry is characterized by uncertainty of construction time, the project cost and scope of work. Hence, the choice of technology and construction organization are crucial. Lean construction represents a promising model of the systematic management of all stages of the life cycle of the construction project, which is focused on reducing the time and cost expenses.

There are a lot of scholars, who explore the theoretical and practical issues of development of the construction organization effective models, in particular, lean construction. Among them the following scholars are allocated: L. Koskela (1992, 2000, 2002), J. Howell (1999, 2003, 2014), G. Ballard (1994, 2000, 2003), A. Mossman (2005, 2009). It is noteworthy that this concept has received wide recognition abroad, both theoretical and practical levels, possible methods of implementation are developed, the tools of lean construction are analyzed. In Russia, the spread of this concept is poorly expressed. The problems of applying of lean construction in the Arctic zone of Russia are quite undeveloped.

If we consider alternative approaches to construction organization, taking into account the specific Arctic challenges, there are construction management approach (DeWitt et al. 2005; United States Department of the Army, 2013) according to the Feasibility Study of the Canadian High Arctic Research Station construction, which was carried out by the PricewaterhouseCoopers to the Government of Canada in 2011 and which overlaps the design and construction phases, meaning construction can begin as the design advances, speeding up the process and includes high level focusing on the planning, scheduling, managing and monitoring; project management in construction (Kimmons, 1989; Lientz and Rea, 1995) according to the “Strategic Assessment of Development of the Arctic: Assessment Conducted for the European Union” 2014 and supports the timely and effective implementation of the scheduled activities and contributes to achieving the objectives of the project according to the given budget; holistic approach in construction (Williams, 2001) aimed at the careful working out of all issues connected with housing and civil engineering with the goal to improve quality of life in Alaska.

Consequently, the goal of the research is to analyze the housing and civil engineering in the Arctic in the context of implementing the methodology of lean construction.

2. Method

Lean construction is a kind of derivative of the lean production concept (Ballard and Howell G., 1997; Howell J., 2014; González et al. 2015; Salem et al. 2006; Howell G, 1999; Mossman, 2009; Belayutham and González, 2014). In the beginning of 1990-ies L. Koskela was one of the first who analyzed the application of the principles of lean production in construction industry (Koskela, 1992, 2000; Alsehaimi and Koskela, 2008; Bertelsen and Koskela, 2004). So, he laid the foundation of lean construction. This concept is a management model that is similar to lean production in part of the pursued objectives, which are based on constant cost reduction, continuous quality improvement and optimization of the speed of material flow according to the logic of just in time. But it has several features in connection with the specifics of the construction field. One of the main distinctive characteristics is the predominant percentage of losses in construction compared with production (Aziz and Hafez, 2013) and a slightly different classification (Formoso et al. 1999). Losses in construction are along with the classical losses which were allocated by Ohno (1988): overproduction; waiting; unnecessary transportation; processing; inventory; unnecessary movement; production of defective products, the replacement is a monetary loss caused by the substitution of more expensive materials (with an unnecessary better performance), performing simple tasks by highly qualified staff or using high-tech equipment instead of the less technological; and the other related to the openness of construction sites (theft, vandalism, inclement weather, accidents). Another distinguishing feature is the nature of the product movement: in industrial production, the products move through the stationary working stations, and in construction, the work areas move through stationary products (Chernykh, 2010). Also, differential moment is a high degree of uncertainty of the construction project because of the scale of activity.

The basis of the algorithm logics of improvement the processes of the lean construction is well-known Deming cycle (PDCA) (Deming, 1982) (figure 1).

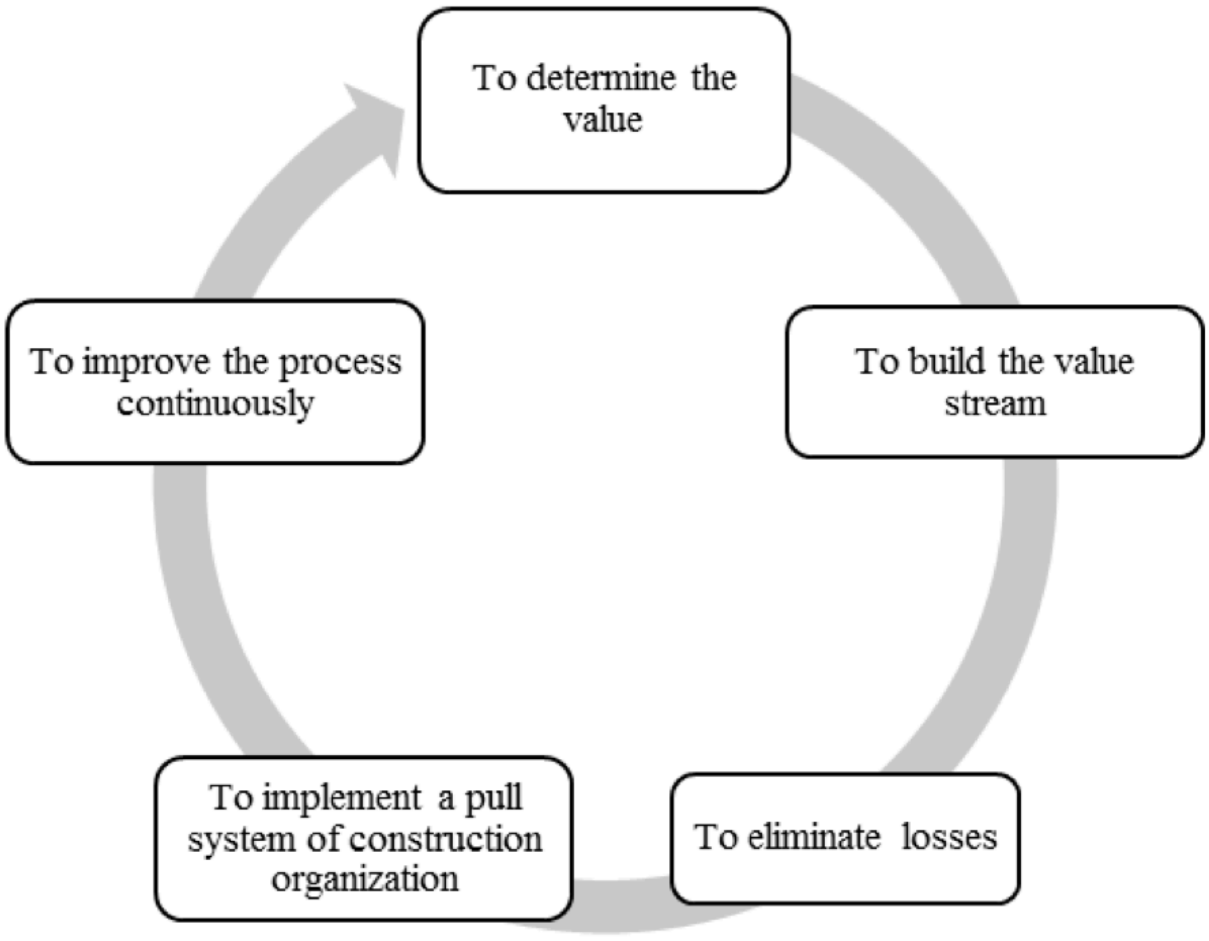

Figure 1. Stages of implementation of lean construction, developed by the authors

Lean construction uses the entire set of tools of lean production and in addition has a number of specific such as:

- the last planner system (the system of operational planning based on the principle "down-up" and covering a period of one week, i.e. weekly and daily schedules are built for two weeks, where the graphs of the first week are working (fully secured by the material resources), and graphs of the second week provide solutions to the logistics works of the second week. The indicator (PPC, percent plan complete) that shows what share of weekly work plan completed on time, is introduced to describe the quality of the development and implementation of schedules. This system is one of the most effective ways to improve construction efficiency through improving the processes of the planning and controlling.) (Ballard, 1994, 2000; Mossman, 2005; Bhargav et al. 2015; Ballard and Howell, 2003);
- concurrent engineering (parallel execution of various tasks using multidisciplinary teams with the aim of obtaining the best products from the point of functionality, quality and performance);
- the planned conditions and working environment in the construction (this tool is necessary to match the conditions for execution of a task with capabilities of workers with the aim of preserving their health and safety).

Unlike traditional approaches to construction organization, which are based on project management techniques, the concept considers the construction process as a value stream creation. Stages of construction constitute the stream logically replacing each other. At that time, in the framework of the established approach: the production process consists of the several subprocesses that transform a variety of resources at the entrance to the finished product at the output and that can be implemented and analyzed separately from each other.

Therefore, the main advantages of the lean construction are:

- reduction of construction costs;
- high quality of the completed construction objects;
- reduction of project turnaround time;
- high degree of controlling of construction project.

3. Results and Discussion

In accordance with the development strategy of the Arctic zone of the Russian Federation and national security for the period up to 2020 one of the priorities is an integrated socio-economic development of the region, which is provided, in particular, improving the quality of life of indigenous peoples and social conditions of economic activity in the Arctic. Accordingly, in order to improve the quality of life of people who are living and working in the Arctic zone of the Russian Federation, including indigenous small peoples, increase their level of social and cultural services and ensure positive demographic developments and necessary social conditions of economic activity are considered, among others, the following activities:

- housing development and upgrading of social infrastructure objects, including educational institutions, healthcare organizations and culture organizations;
- housing renewal and housing modernization, upgrade and modernization of the fixed assets of housing and communal services on the basis of modern energy saving technologies;
- active formation in the cities, small villages and towns new available for all segments of the population and mobile multifunctional cultural institutions.

The state program of the Russian Federation "Socio-economic development of the Arctic zone of the Russian Federation for the period till 2020" is the main mechanism for the implementation of the aforementioned strategy, in which the goal is the formation and development of the local livelihood systems in the region, where housing and civil engineering plays an essential role. Therefore, this problem must be realized through the implementation of projects directly in the field of housing construction along with the construction of socially significant objects equipped with network engineering and technical support. Basis for the creation of the positive trends in the implementation of such projects is the financing on the required scale, focused on the mechanisms of the public-private partnership. By 2020 in the context of this challenge, the achievement of the following values of some targets is provided:

- average population of the Arctic zone will be 2341.2 thousand people;

- total area of living spaces will reach 25.9 sq.m in average per one resident;
- rate of the natural increase of the population of the Arctic zone (per 1000 persons) will grow by more than threefold and will amount to 9.5 persons per 1000 persons of the population.

3.1. Characteristics of housing and civil engineering in the Arctic zone

The combination of extreme environmental conditions with low socio-economic development of the region predetermined the difficult conditions for construction. The process of housing and civil engineering has many engineering features. Objects have to be built on unstable terrain under which the soil is mixed with ice. In the permafrost the surface is constantly changing its structure. Built structures heat the soil, and it loses solidity, begins to melt and shift. For example, in Canada, which also represents the Arctic, the residents of two small towns were forced to leave their homes for this reason. Therefore, it is possible to build the foundation of buildings on permafrost, only by taking special measures to maintain constant temperature of the soil. The construction of the foundations must necessarily be accompanied by an engineering-geocryological investigations in order to adequately predict the behavior of soil during the construction and subsequent operating of buildings. Calculations of the thermal regime of soils are performed and the type of foundation is determined after the engineering studies. There are two principles on which the use of permafrost as the foundation of buildings is based. The first principle is the aspiration to maintain the permafrost in its natural state (the most popular and affordable solution). Under the second principle, a building is designed with the expectation that the foundation of the house will be in a thawing condition (Smirnov, 2015):

1) in accordance with the first principle, the permafrost Foundation remains in its original state not only in the process of building construction, but during its subsequent operation. This principle is applied in situations where preservation of the frozen soil in its original state is cost-effective. The easiest way is to build a foundation on a sandy ground, which is not classified as plastic-frozen. For the latter cases, activities to reduce the temperature of the base to the calculated values are additionally provided, and possible plastic deformations of the base under the loading are considered in the calculations of the foundation. Following this principle mainly pile or pier foundations are satisfied. But, for example, strip foundation may also be the solution. The only one condition is to not give the top layer of soil to change its properties under the influence of heat from operated object. For this purpose, the underground is made cold, ventilated through the produhi in zabirka or the basement of the house. Also, a solid insulation layer with high insulation properties under the building can be performed. This will keep the soil in its natural state. Also, it is important to determine the depth of the soil. For different types of structures, its value is assigned separately:

- for pile foundations, the depth of laying should not be less than 2 m greater than the thickness of the layer of soil that freezes and thaws seasonally. The calculation is done on that layer of the permafrost soil will provide the required resistance to compression;
- for all other types of foundations, the depth of laying is set greater than the thickness of the seasonal thawing soil at 1 m;
- if the construction of the building on an artificial material with prescribed characteristics is designed, the depth of laying the soles is not standardized and it is based on the conditions of construction;

2) the second way is used less frequently and under conditions when the soil at the construction site is not heaving or subsidence and when in terms of temperature fluctuations, the soil deformations do not exceed the maximum permissible values. In this case, it is necessary either to thaw out the soil before construction of the foundation, or make all important calculations, and to assume that the foundation will thaw during the operating of the building. Construction of the building’s basis involves the calculation of the depth of laying of the foundation sole in the comprehensive assessment of the thickness of the seasonally freezing soil and level of ground waters, focusing on the zone of thawing. And it will be formed in the subsequent operating of the building.

A specific choice is made by comparing the technical and economic calculations and the effectiveness of the considered solutions.

The necessity of application of pile foundations and thermo-insulating and innovative energy-intensive materials for construction of buildings walls in severe climatic conditions creates significant costs. For many areas in the Arctic region, such construction becomes uneconomical. For example, in Norilsk, the price of 1 sq. m of real estate is about 22 - 26 thousand rubles on the secondary market and the cost of construction of 1 sq. m in low-rise apartment building is about 75 thousand rubles. The example is significant from the point of view that Norilsk is allocated from the set of settlements included in the Arctic zone of the Russian Federation, by positive trend in population (in 2012 – 177273 people; in 2013 – 177738 people; in 2014 – 176559; in 2015 – 176251 people; in 2016 – 177428 people, according to the data of the Federal state statistics service of the Russian Federation).

In Arctic, the accumulation of damages in the protective and decorative coverings and construction materials happens many times faster than the Average strip of Russia, because of the rapidly flowing vapor condensation processes under changing temperature and humidity conditions. Intense destruction is caused by the volume expansion of water in construction materials when it is freezing. Errors of the design, construction and operating of real estate quickly manifest. Correction of defects in the Arctic zone costs many times more expensive than in other areas (Varfolomeev, 2014). In turn, the physical deterioration of buildings quite early reaches critical values, which mean the assignment to the category of dilapidated housing. The overhaul of such objects is difficult and often economically inefficient.

Thus, the construction in Arctic can be described as a costly project that requires the highest quality and rapid pace of work and, consequently, reduced construction time compared to the objects located in more enabling environment.

In relation to Arctic territory, the flowing process of lean construction is presented schematically (figure 2).

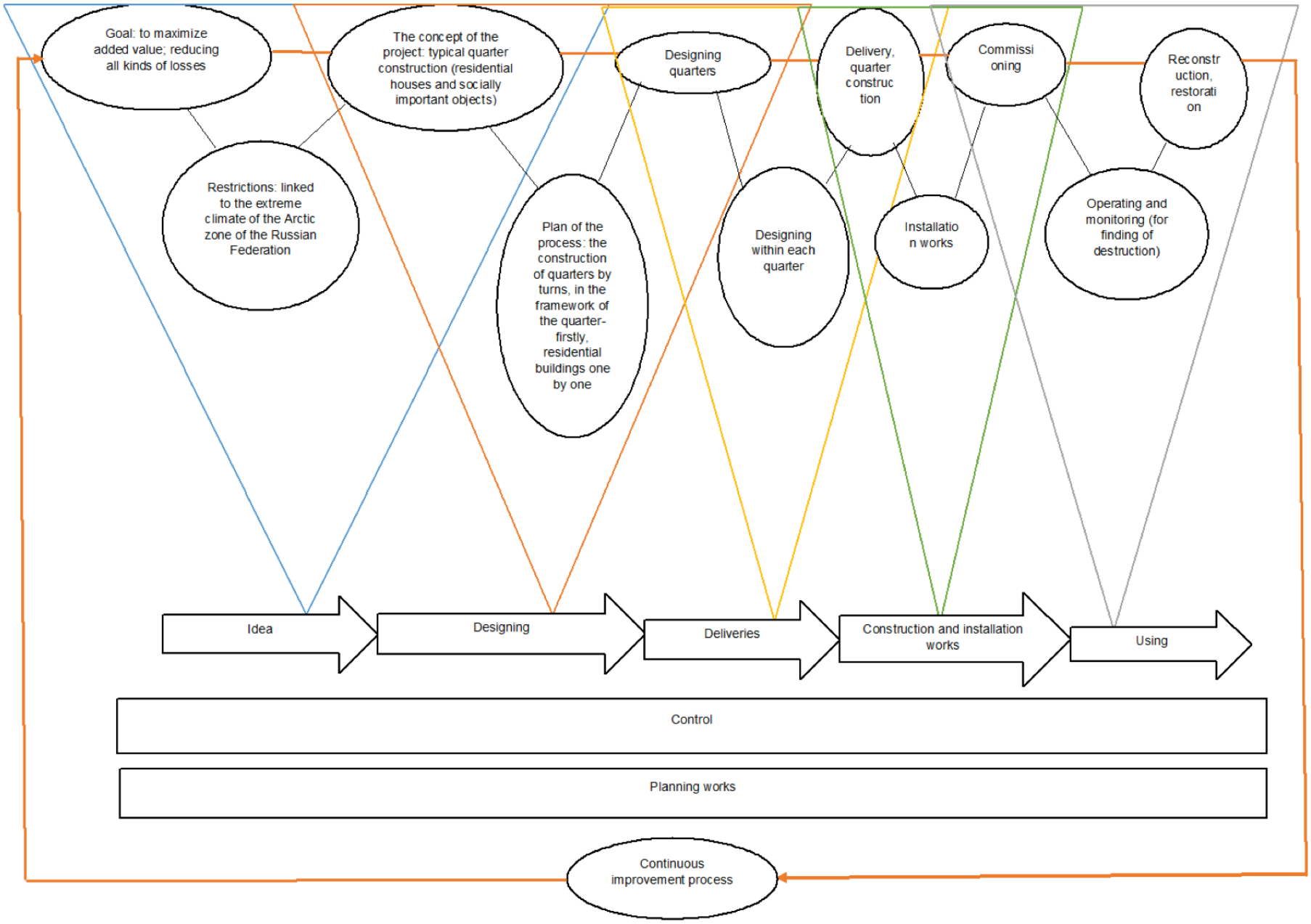

Figure 2. The scheme of lean construction in the Arctic zone of the Russian Federation, developed by the authors

The significant role in the implementation of this construction organization model is given to the last planner system. The project of the low-rise residential building in Norilsk, which considers the characteristics of the Arctic in relation to construction and installation works is shown in figure 3.

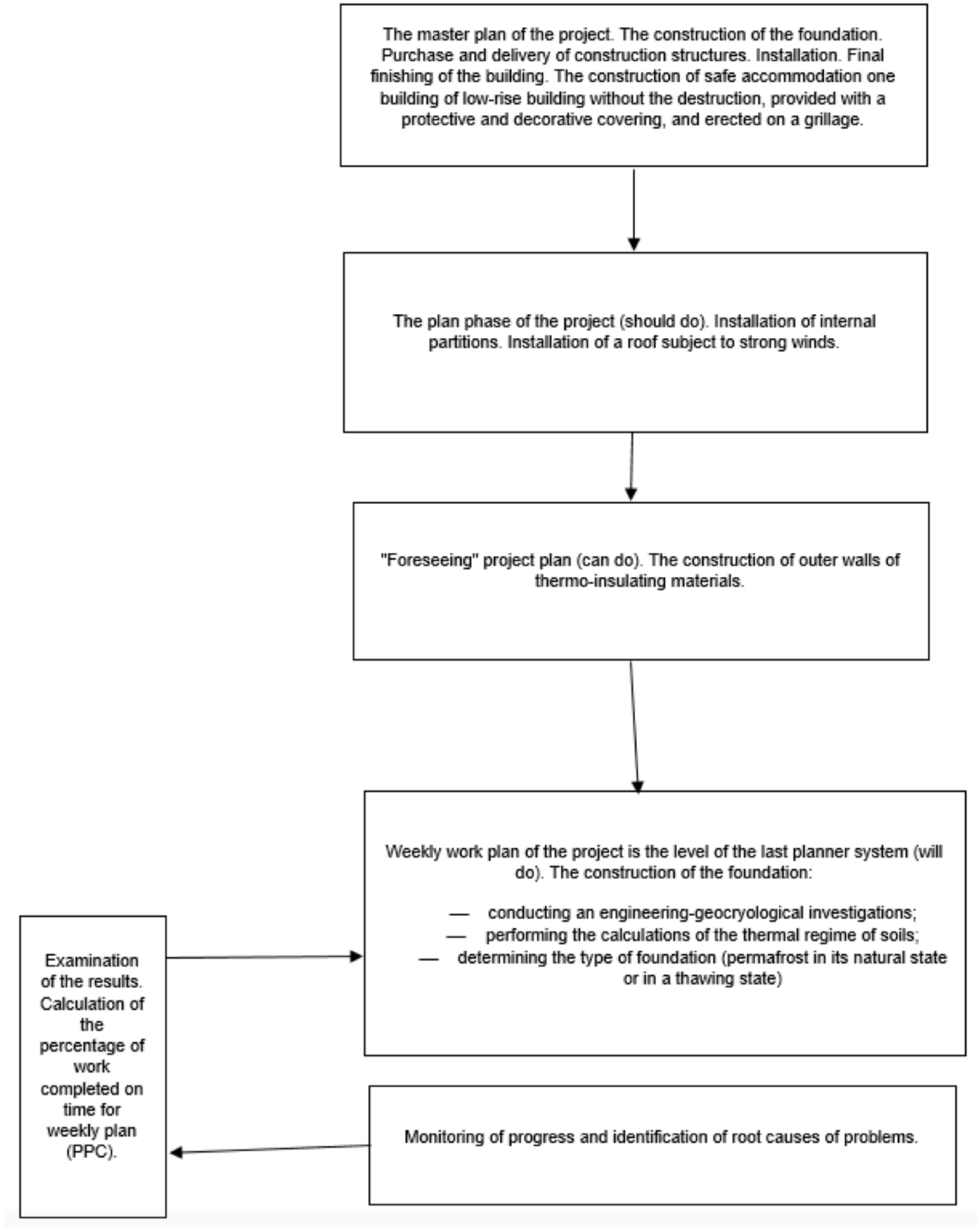

Figure 3. The scheme of operational planning of construction, developed by the authors

So, it is possible to highlight the core features of housing and civil engineering in the Arctic zone of the Russian Federation:

- high cost of construction, which pushes private developers, along with insufficient state financing;
- required high professionalism of employees in terms of the design and construction of objects related to the effects of harsh climatic conditions;
- execution of typical projects;
- limited construction time.

Clearly, the main features of lean construction adequately meet the requirements, that apply to models of the housing and civil engineering in the Arctic regions of Russia and they are able to reach the target results. Due to the state support of development of the Arctic at the highest

level, the issue of progress of infrastructure of life support for the population of the region, consisting for the most part in the development of residential objects and socially significant objects, is reduced to the rational methodology of construction organization. Certain peculiarities of lean construction contribute to a new, large-scale development and accelerated infrastructural development of the region.

4. Conclusions

In summary, the following conclusions should be highlighted:

1. high degree of importance of the Arctic as a strategic object is emphasized;

2. problems of socio-economic development of the Arctic zone of the Russian Federation in part of life-support systems creating are actualized;

3. features of the housing and civil engineering in the Arctic zone of the Russian Federation are systematized;

4. lean construction, which goal is to reduce costs and construction time, in conjunction with high quality of construction, has all the prerequisites to become a breakthrough development strategy;

5. lean construction in the context of the Arctic regions may become the first large-scale example of implementation of this concept in Russia;

6. analyzed construction organization model - lean construction is capable to be compared with the alternatives models in the foreign arctic countries and become the winning strategy.

This study is attractive not only for Russian part of the Arctic, but also for other Arctic countries: USA, Canada, Norway and Denmark. These countries are forced into the same harsh Arctic conditions, which need to be overcome. In this case, in the context of housing and civil engineering, lean construction as a model of construction organization is proposed. According to the results of the study, this methodology is suitable and viable for Russia. The implementation of this model in Arctic regions (different from Russia) also looks effective. Lately, the Arctic has become a prominent strategic object in world politics, so its development, including from the construction point of view, is a priority for the Arctic regions. And Russia has an active position, in the first place, because of the support at the state level. Therefore, Russian Arctic can be an example in the organization of construction for other Arctic countries. In summary, lean construction is a promising way of organizing housing and civil engineering both for the Russian part of the Arctic and its foreign parts.

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