Organizational and Technological Procuring of Roofing Devices with Greening Systems

E A Korol¹, N S Shushunova¹, A L Mayilyan¹

¹Moscow State University of Civil Engineering, 129337, 26, Yaroslavskoye Shosse, Moscow, Russia

E-mail: nshushun@gmail.com

Abstract. With an increase in the density of urbanized areas in order to create a comfortable living environment, organizational and technological solutions for exploited roofing with landscaping systems have found application in construction practice. Traditional rooftop technology is not always suitable for roofing with greening systems. The use of green space on the coatings of buildings and structures changes the specifics of the production of roofing work in the construction process, taking into account the adopted structural and technological solutions. These decisions in most cases have characteristic features that must be considered in the process of formation of the composition and sequence of technological processes and operations, as well as the choice of rational organizational and technological procuring of roofing devices with greening systems.

1. Introduction

In the modern urbanized techno-cities the role of nature is extremely important. Inventions that include technologies, which help people to save environment, are becoming more and more successful. Nowadays smart solutions of green roofs are popular for their ecological, technical, economic benefits and aesthetic qualities. Roofing devices with greening systems are used in residential, commercial, public buildings and even transport highways. The largest transport highway is passing through Denmark, Austria and Germany [7-9], which is called «Green roof», shown on the Figure 1.
The development and study of rational organizational and technological procuring of roofing devices with greening systems when constructing a multi-layer construction of roofing coatings is aimed at balancing the additional labor costs arising when constructing roofs in order to reduce the time, laboriousness and improve the quality of construction [6] and sustainability risk management [18,19]. These challenges can be overcome with the of new cost effective green roof design that can work more effectively and efficiently in any space [1]. It always mates with the development of the International standardization due to installation of green roofs [3,12,13].

The innovative energy-efficient construction technologies will bring great benefit to the ecology and help to relief the heat island effect. We create and designed green rooftop spaces [2,10]. Ergonomic design is provided the installation in various roof configurations and types such as multi-level modular green roof system (Figure 2).

**Figure 1.** View from the Hamburg's highway burial project.
The device of greening systems with adjustable supports [14,17] on roofing covers leads to an increase in the labor intensity and duration of the construction of construction objects in general. The decomposition of the designed multi-level modular green roof system into separate structural elements made it possible to perform a description of the sequence of their installation in the design position during the constructive works, forming the organizational-technological models. Research of high-tech developments in the field of construction will help to find a solution for green roofing [4,5,20].

2. **Formation of organizational and technological models of technological processes**

To implement and improve the efficiency of scheduling, adaptation and use of new scheduling tools is required, with the addition of their development and introduction of new mathematical methods and new engineering software [11,15,16].

In order to implement the streamlining of work operations during the construction of roofing with the device of a modular system, it is proposed to perform the following measures:

- modeling of construction processes with the release of the organizational-technological and functional model of the device modular green roof system;

- development of formalized methods for streamlining technological operations included in the technological processes of the device modular green roof system and the formation on their basis of organizational and technological models. The most significant characteristics of organizational and technological models include unit labor costs, as well as the composition of the performers of technological processes and operations;

- formalization of methods for streamlining of models of technological processes for installation of the modular green roof system.

This study describes a formalized approach to the formation of organizational and technological models of the device modular green roof system and the definition of technical characteristics: specific labor costs, performers of technological processes and operations of the device modular roofing system. This approach was made on the basis of the principles of saving labor and time. Improving labor productivity is achieved by improving the organization of the
workplace, a clear distribution of responsibilities among workers, taking into account the division of labor and the maximum possible combination of technological operations.

As a result of the technological streamlining of these operations, an organizational-technological model of the modular green roof system has been formed (Figure 3).

| Technological Processes and operations | Working time, min |
|---------------------------------------|------------------|
| Installation of adjustable supports with a pitch of not more than 1 m | 20               |
| Coating Layout                        |                  |
| Layout and gluing supports            | 22               |
| Adjustment of a tilt angle of a support | 40             |
| Fixing special clips                  | 14               |
| Installation of 1x1 m flooring grid   |                  |
| Laying floor grating on supports      | 25               |
| Fixing the grating                   | 17               |
| Installation of modules for greening  |                  |
| Installation and connection of a group of modules in the amount of 4 units | 22               |
| Fixing a group of modules to the flooring grid | 20               |
| Filling a group of modules with planting material | 30               |

The schedule of distribution of labor resources - workers (W)

W1 W1 W1 W1 W1 W1 W1 W1 W1 W1 W1 W1 W1
W2 W2 W2 W2 W2 W2 W2 W2 W2 W2 W2 W2 W2
W3 W3 W3 W3 W3 W3 W3 W3 W3 W3 W3 W3 W3

Figure 3. Organizational-technological model of the device of the operated modular green roof system.

In this case, indicators of the duration of each process are set taking into account the identification of a rational duration of work and their maximum combination. Thus, the duration of the work is reduced by 38% (from 210 to 130 min), provided that the works are combined. The performed fragmentation into layers is introduced to evaluate technological operations that can be performed in parallel (Figure 4).
Figure 4. The scheme of fragmentation into layers of the functional model of the device of the operated modular green roof system.

The total duration of a set of works (operations) can be defined according to the following formula:

\[ T = t_n + \sum_{i=1}^{n-1} (t_i - \mu_i t_i), \]

where \( T \) - the duration of the execution of all works (operations);
\( t_n \) - the duration of the last work (operation);
\( \mu_i \) is the coefficient of combining in time \( i \) and \((i + 1)\) works (operations).

3. Results and conclusions

Thus, the duration of the work is reduced from 210 to 130 min (38%), provided that the works are combined. Due to the rational allocation of resources and the combination of work, as well as their mutual coordination in time and space, it is possible to determine the rational organizational and technological parameters of technological processes of the device modular green roof system by building an organizational-technological and functional model.

In the course of the work, the sequence and composition of technological processes and operations were established during the installation of the developed constructive-technological solution of the collapsible modular system of the operated roofing surfaces.

The organizational-technological model was also constructed as a result of the formation of technological and spatial ordering of technological processes, and a scheme for dividing into layers a functional model of operated modular green roof system was developed.
The process of forming the composition and sequence of technological processes and operations as part of an organizational-technological model is an important rational component of the organizational-technological procurement of roofing devices with greening systems.

References
[1] Shafrique M 2018 Green roof benefits, opportunities and challenges Renewable and Sustainable Energy Reviews vol 90 pp 757-773
[2] Korol E and Shushunova N 2016 Benefits of a Modular Green Roof Technology Procedia Engineering vol 161 pp 1820-1826 https://doi.org/10.1016/j.proeng.2016.08.673
[3] Korol E, and Shushunova N 2016 Research and Development for the International Standardization of Green Roof Systems Procedia Engineering vol 153 pp 287-291 https://doi.org/10.1016/j.proeng.2016.08.117
[4] Korol O A 2015 Research and knowledge-intensive developments in the field of energy-efficient construction production Construction Materials 6 pp 13-15
[5] Viola S 2017 Green roofs for built environment recovery: technological transitions Journal of Cleaner Production vol 153 pp 592-599 https://doi.org/10.1016/j.jclepro.2016.03.052
[6] Sugak E B 2013 On some of the official duties of security specialists Labor in Germany Man and work 10 pp 48-51
[7] Underground space as an indicator of urban development: quantitative assessment of the use of underground space http://www.undergroundexpert.info/stati-i-doklady/item/1696-podzemnoe-prostranstvo-kak-indikator-gorodskogo-razvitya.ru/
[8] Hochtief Aktiengesellschaft https://www.hochtief.com/hochtief_en/0.jhtml
[9] Kasyanov V and Chernysheva O 2019 IOP Conf. Ser.: Mater. Sci. Eng. 471 112052
[10] On-line: https://www.grooflab.com/home-4-de
[11] Korol E, Kagan P, Barabanova T, Bunkina I 2016 Description of technological processes in construction using formal language International Journal of Applied Engineering Research vol 11 3 pp 1691-1693
[12] BREEAM UK New Construction Technical Standards On-line: https://www.breeam.com/discover/technical standards/newconstruction
[13] LEED for Building Design and Construction (LEED BD+C) On-line: http://leed.usgbc.org/bd-c.c.html.
[14] Buzon Pedestal International On-line: http://www.buzon-world.com/en/page/about-us
[15] Kagan P, Naumova A, Vilman Y 2016 The problems of project management software implementation in construction corporations MATEC Web of Conferences 07016
[16] Kagan P The engineering communication networks - the issues of use of standards for the information representation in design, construction and operation Procedia Engineering 153 pp 261-265
[17] Korol S, Shushunova N and Shushunova T 2018 Innovation technologies in Green Roof systems Matec Web of Conferences vol 193 04009 https://doi.org/10.1051/matecconf/201819304009
[18] Roe R, Bardenwerper W, Borkovskaya V G 2018 Using a Case Study Interactively to teach Sustainability Risk Management MATEC Web of Conferences vol 251 06028 DOI: https://doi.org/10.1051/matecconf/201825106028
[19] Borkovskaya V G, Degaev E, Burkova I 2018 Environmental economic model of risk management and costs in the framework of the quality management system MATEC Web of Conf. 193 05027 DOI: https://doi.org/10.1051/matecconf/201819305027
[20] Spala A 2008 On the green roof system Selection, state of the art and energy potential investigation of a system installed in an office building in Athens (Greece) Renewable Energy vol 33 1 pp 173-177