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Management and engineering solutions for railway station development

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ABSTRACT This paper presents a methodology for construction engineering management of railway station redevelopment. The station working capacity is taken into account and the stages of preliminary and main works are determined. The scope of work to be performed by a building contractor is substantiated to provide an optimal station performance. The volume and scopes of work for specific and complex construction workflows are grouped by the components of the railway marshalling yard.

The optimal volume of work of the complex flow *F* has been determined (as a percentage of the total estimated cost of the facility). The station working capacity *Nв* has been taken into consideration in correlation with the given conditions of construction or renovation works.

The key construction flow management options have been worked out based on the optimal index of construction work sequence, prime cost reduction of construction and installation works (current costs *C*), and effective capital investments into machines and mechanisms (one-time costs K_f).

The proposed methodology for construction management and engineering solutions is oriented to general contracting and subcontracting companies of the railway construction sector. This methodology is intended to lower the prime cost of construction and installation works and to reduce the time of construction and redevelopment of railway stations.

KEYWORDS: railway stations; coefficient of construction sequence; volume of work; construction flow system; station working capacity; generation of work scopes; rational coefficient of construction sequence; optimization methodology; optimization of management and engineering solutions; technological layout; coefficient of construction flow sequence

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Научная статья

Разработка организационно-технологических решений по переустройству железнодорожных станций

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АННОТАЦИЯ Разработана методика организационно-технологического проектирования переустройства железнодорожных станций. Учитывается перерабатывающая способность станции и определяется порядок этапности осуществления подготовительных и основных работ. Обосновывается размер фронта работ подрядной строительной организации, позволяющий обеспечить оптимальную производительность станции. Объемы и фронты работ для специализированных и комплексного потоков группируются по элементам железнодорожной сортировочной станции.

Определена оптимальная величина (в процентах от общей сметной стоимости объекта) размера фронта работ комплексного потока *F*, которая рассчитывается по величине оптимальной для данных условий производства строительных или реконструктивных работ, перерабатывающей способности станции *Nв*.

Разработаны основные варианты организации системы строительных потоков по критерию оптимального коэффициента совмещения, снижения себестоимости строительно-монтажных работ (текущие затраты *C*); эффективному использованию капитальных вложений в машины и механизмы (K_f единовременные затраты).

Предлагаемая методика выбора организационно-технологических решений предназначена для деятельности генподрядных и субподрядных организаций железнодорожного строительства; позволит снизить себестоимость строительно-монтажных работ, сократить сроки строительства и реконструкции железнодорожных станций.

КЛЮЧЕВЫЕ СЛОВА: железнодорожные станции; коэффициент совмещения; фронт работ; система строительного потока; перерабатывающая способность станций; формообразование комплекса работ; рациональный коэффициент совмещения; методика оптимизации; оптимизация организационно-технологических решений; технологическая компоновка; коэффициент совмещения потоков

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INTRODUCTION

Modern methods of planning, designing and implementation of work on construction and development (or/and re-development) of railway stations and junctions are characterized by a variety of construction management and engineering solutions and the best ones are chosen [1–4] taking into account the following aspects:

- sequence of specific, facility-level and complex construction flows;
- phases of construction and separate commissioning of yards, tracks and station facilities;
- management and engineering solutions for the basic labour-intensive work on construction and upgrading of the earth bed, artificial facilities, water supply system, servicing facilities, railway automation and telemechanic devices, as well as the entire complex of track-laying and ballasting works;
- requirements to ensure safety of work and train movement on the construction site.

It is necessary to develop a methodology for management and technological planning of railway construction facilities to generate effective decisions on railway station reconstruction, reduction of the estimated cost of construction, optimization of construction time, reduction of construction work costs, and making better use of construction machines and transport.

MATERIALS AND METHODS

The materials used in the survey are the design documentation sections on construction and redevelopment of railway marshalling yards, design documentation on construction management plan (CMP), and complex management and engineering designs on the construction of complex facilities connected with train movement.

Marshalling yards are part of a large class of rail freight station systems designed to receive, handle and distribute freight car flows according to their destinations. The main components of such stations are receiving park (RP); sorting park (SP) and dispatch park (DP) [5, 6].

The sequence and phases of preparatory and main works is determined taking into account the working capacity of the station. The scope of works to be completed by a building contractor is substantiated so that the optimal working capacity of the station can be ensured.

During the construction and redevelopment of railway marshalling yards and phased commissioning of facilities, the work is carried out while trains are running on existing or new tracks [4, 7–9]. Specific and complex construction flows are grouped into the following types of works:

- construction of interconnection tracks;
- construction of new main tracks;
- extension of receiving-and-departure tracks;
- reconstruction of existing humps;
- construction of additional marshalling systems;
- laying of additional access tracks;
- reconstruction of turnouts and lead track switches;
- reconstruction and upgrading of railway automation and telemechanics systems (RAT) of receiving-and-departure tracks;
- construction and upgrading of power supply systems;
- reconstruction and upgrading of railway signalling (RAT) and humping equipment of marshalling systems.

The linear character of the facilities and continuous train movement can cause difficulties in delivery and storage of materials and machinery at the construc-

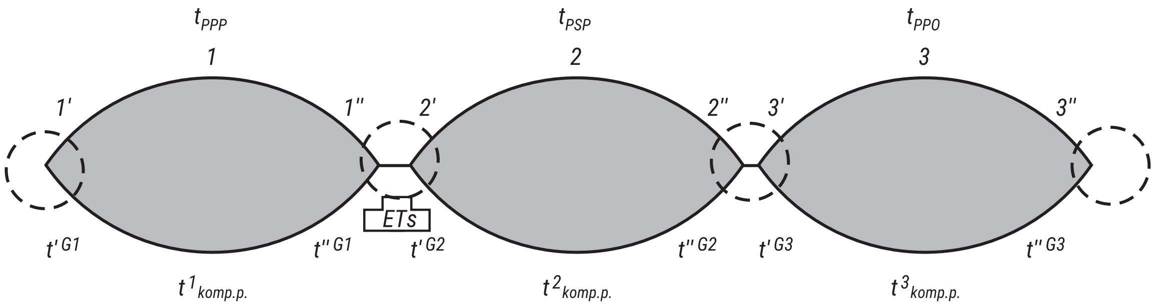

Fig. 1. Scopes of specific workflows during construction and redevelopment of a marshalling yard: 1' is entry neck of receiving park (switches, retarders); 1 is track structure (TS) of receiving park; 1" is exit neck of receiving park; 2' is entry neck of sorting park (SP); 2 is TS of sorting park; 2'' is exit neck of sorting park; 3' is entry neck of departure park (DP); 3 is TS of departure park; 3'' is exit neck of departure park; t_G is duration of specific flow for neck construction; t_{PPP} is the time for laying TS of RP; t_{PSP} is the time for laying TS of SP; t_{PPO} is the time of laying TS of DP

tion site, hence making it difficult to use them at the scheduled time intervals. This complicates smooth construction workflows and entails downtime of works. It is also a managerial and technological challenge to estimate the exact scopes and terms of construction works when the railway station facilities are commissioned in phases [10, 11].

Volumes and scopes of specific and complex construction flows are grouped by railway marshalling yard components (*Fig. 1*).

Technological layout of specific construction flows includes:

- installation of switches and station neck tracks;
- laying station yard tracks;
- installation of railway automation devices and connection of necks and tracks to the electric interlocking system;
- construction of artificial structures;
- construction of electrification lines;
- construction of servicing and technical buildings.

$T_{sr.s.s.} = (t_{1komp.p.} + t_{2komp.p.} + t_{3komp.p.})K_s$ is the duration of complex construction or reconstruction flows of a marshalling yard and it is equal to the duration of construction flows of the receiving park (1), sorting park (2), and departure park (3) taken together taking into consideration the coefficient of construction sequence K_s

$$t_{1komp.p.} = t'_{G1} + t_{PPP} + t''_{G1};$$

$$t_{2komp.p.} = t'_{G2} + t_{PSP} + t''_{G2};$$

$$t_{3komp.p.} = t'_{G3} + t_{PPO} + t''_{G3};$$

$$K_s = [K_{Spp}; K_{Ssp}; K_{Spo}].$$

The scheduled time for the construction of a marshalling yard:

- t'_{G1} is the time of installation and laying the RP entry neck switches;
- t_{PPP} is the time of RP track laying;
- t''_{G1} is the time of installation and laying the exit neck tracks of the receiving park RP;
- t'_{G2} is the time of installation and laying the entry neck switches of the sorting park SP;
- t_{PSP} is the time of laying the sorting park tracks SP;
- t''_{G2} is the time of installation and laying exit neck tracks of the SP;
- t'_{G3} is the time of installation and laying the entry neck switches of the departure park DP;
- t_{PPO} is the time of the departure park tracks;
- t''_{G3} is the time of installation and laying of switches of the departure park.

The design of a complex construction flow for the construction or redevelopment of a marshalling yard should take into account the following specifics:

a) construction flows should not interfere with the main tracks and switches on the train routes across the station;

b) the station tracks and switches should be occupied for the shortest possible time;

c) extensive volumes of work should be divided into phases;

d) each phase should provide the optimal scope of uninterrupted work, comprehensive mechanization of construction, efficient use of machinery, and highly productive crews.

RESULTS AND DISCUSSION

The scope and type of each phase (scope of work) should be calculated in accordance with the general volume of main works on the station development, scheduled construction time and the minimal possible disturbance of the station's working capacity [12–15].

The studies (*Fig. 2*) conducted by the authors have shown that the optimal value (as a percentage of the total estimated cost of the facility) of the scope of complex construction work flow F is determined by the value of the optimal working capacity of the station N_P for given conditions of construction or renovation work.

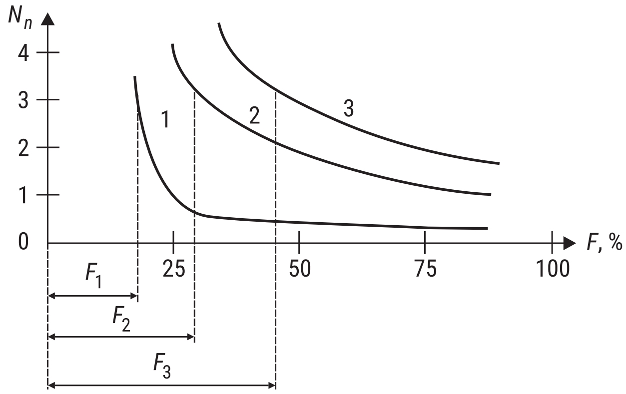

Fig. 2. Dependence of the railway station capacity (N_p, thous. carriages/day) on the volume of work scopes F of streamlined construction flows where F_1, F_2, F_3 are the scopes of preliminary construction workflows before reducing the working capacity of the corresponding stations (1 — during construction of railway marshalling yard; 2 — during reconstruction of stations equipped with hump and successive car distribution; 3 — during reconstruction of stations with parallel car distribution)

The specific construction flows include:

— specific construction flows for separate parks (with allocated work scopes within the corresponding park) including part of station necks;

— end-to-end specific construction flows.

Construction machines such as jib cranes and track-laying cranes for laying track switches and pre-assembled track lengths by elements and blocks can be a variable parameter. The sustainability of railway construction solutions is measured by the appraisal system with different variant parameters. This system includes natural, financial, managerial, technological and other performance criteria.

The analysis of the existing preparation work to be carried out for the railway station redevelopment shows that the standard technical specifications and different surveys describe separate factors without the relationship between them. Different options should be evaluated based not only on the technological work sequencing analysis (e.g., coefficient of construction flow sequence), but also on the financial analysis of the given facility construction. To design rational management and engineering models for the station redevelopment, it is necessary to identify and use these interrelated factors effectively.

Initially, the key model (with maximum scheduled time) is designed based on the standard input data, standardized time values and production flow charts for a certain type of construction. To manage railway construction more effectively, it is necessary to look for a variant with reduced construction time and an effective distribution of resources. Therefore, the initial data of the work time schedules as well as the management, engineering and economic indicators are adjusted to reduce the work scheduled time and make more effective utilization of the machinery, work force and financial resources.

Every next variant is designed based on the shortest possible construction time with the best possible workflow sequence, the highest possible rhythm of work and the maximum intensity of work without interruption. A shorter work production time with improved management and engineering indicators increases the concentration of capital investments in the construction of the facility and capital assets. However, a variant‘s productivity depends on the reduced costs of construction and installation works. At the same time, a variant's productivity may depend on different combinations of the calculated cost components.

After the work scopes and technological charts are established, different time schedules with the defined workflow sequence coefficients are drawn. They are:

- K_{srp} is the coefficient of work schedule sequence of the receiving park (RP);
- K_{srp} is the coefficient of work schedule sequence of the sorting park (SP);
- K_{sro} is the coefficient of work schedule sequence of the departure park (DP).

The optimal variant is one with the rational sequence coefficient of K_s. The key variants of construction flow management based on the optimal coefficient of workflow sequence, reduction of the cost of construction and installation works (current costs S), and effective utilization of capital investments in machines and mechanisms (one-time costs K_j) have been developed by the authors.

The value of the rational sequence coefficient for different management and technological charts (*Fig. 3*) corresponds to the intersection of dependence curves of current costs on the cost of works ($\Delta C_{1\text{-}j}$) and one-time costs in the form of capital investment ($\Delta K_{F1\text{-}j}$).

This graphic correlation gives a general understanding how to determine a rational management and technological indicator. In this aspect, several op-

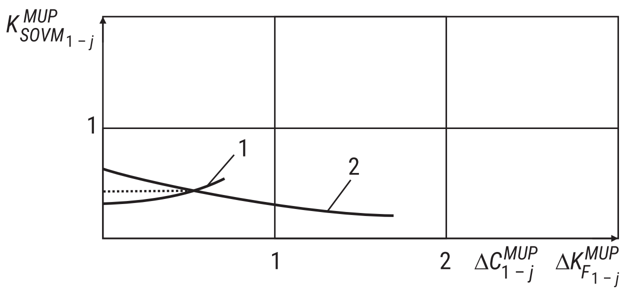

Fig. 3. Determination of the rational sequence coefficient: 1 is $K_{SOVM} = f(\Delta KF_{1\text{-}j})$; 2 is. $K_{SOVM} = f(\Delta C_{1\text{-}j})$

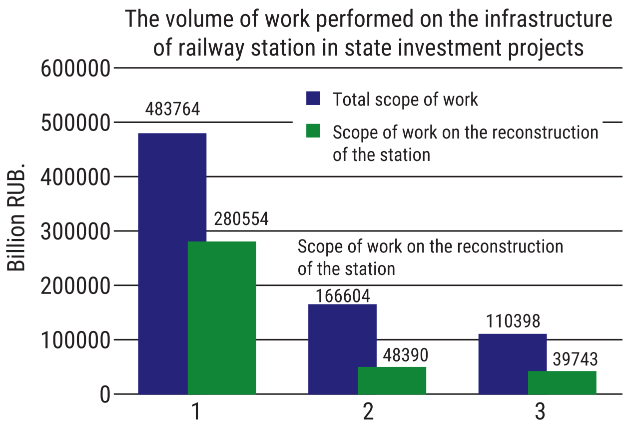

Fig. 4. Dynamics of investment in the construction and redevelopment of railway stations (investment projects of the railway infrastructure development): 1 — at the North – West ports approaches; 2 — at the the Azov – Black Sea ports approaches; 3 — at the BAM eastern part

tions of rational indicators can be determined depending on the components influencing the economic effect (e.g. reduced cost of work, reduced cost of capital assets, etc.).

The study showed that changes in management and technological indicators have the greatest effect on the change of construction and installation work costs (the correlation ratio is 0.802), particularly, such components as the cost of construction machine and device operation (the correlation ratio is 0.908) and the cost of production workers' wages and salaries (the correlation ratio is 0.807).

The schedul models for redevelopment and construction of station infrastructure within the state investment project of railway infrastructure development were analyzed. The volume and type of each phase (work scope) was established depending on the total volume of the station general development, specified construction time with the minimal disturbance of the station working capacity.

The proposed method for the station's management and technological optimization of construction is of current interest because national projects on railway transport development [1] envisage a large volume of work (30–40 % of the total) on the construction and renovation of station infrastructure facilities (*Fig. 4*). The efficiency of construction production management can be increased by defining a rational amount of resources within a limited work scope. Therefore, considering the increasing volumes of this type of construction, the proposed method will reduce the cost of construction and installation works, and shorten the time of construction and renovation of railway stations.

The dependence of management and engineering parameters on technical and economic parameters has so far been poorly investigated due to insufficient statistical data because of the difficulty of generating a large number of time schedule models. The proposed method for optimal work scheduling calculations uses the diagrams obtained from the Microsoft Project system, which makes it possible to automatically determine the variant's technical, economic, management, and engineering parameters given the specified scopes and resources. The variant's cost estimation can be imported with the help of the GOSSTROYSMETA cost estimate programme as it contains an MS Project estimate export.

CONCLUSION

The proposed method for management and engineering solutions is designed for general contracting and subcontracting railway construction companies. The above mentioned dependencies can be interpreted on the level of work production projects (WPP), work management projects (WMP) and construction management projects (CMP) based on different parameters. For example, at the WPP level, it is sufficient to use the parameter of cost changes in construction and installation works and capital investment changes in capital assets by changing management and engineering indicators. At the WMP level, the effect of early commissioning of a railway station facility should be taken into account. At the CMP level, the effect of capital investment distribution and the effect of early commissioning of the entire station complex into operation should be taken into account as well.

The analysis of time schedule models for reconstruction and construction of station infrastructure facilities included in the state investment project of railway infrastructure development at the North-West ports approaches showed that the cost parameters were reduced by 6–8 % of the total estimated cost of the facility. It was possible due to the use of the method of choosing the optimal work management model for marshalling yards. As the industry guidance documents have not been updated for a long time, the methodology presented in this paper can be of great practical importance.

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