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Methodological problems of assessment of organizational and technological reliability in construction management of linearly-extended structures

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Abstract: In the article, results of researches of modern planning methods and management of linearly-extended structures are considered and generalized; the assessment of their efficiency is given. Recommendations about ensuring rated level of organizational and technological reliability are provided.

Key words: Linearly-extended structures, Quality, Construction, Planning, Management, Rated level, Model, Organizational and technological reliability, Forecasting

1. Introduction

By the linearly-extended structures (LES) are accepted that constructions the linear dimensions of which are defined as in the scope of work as in the technology of their construction. Linearly-extended structures differ in a considerable constructive variety and intend for the solution of numerous industrial and social tasks. In the construction of LES, it is possible to carry engineering networks and communications, highways and railway tracks, the equipped water channels and ways, tunnels, and mines of different function. Each version of LES possesses certain constructive decisions which are implemented by means of specific technologies. General properties of the construction of LES are sufficient monotony of building constructions on the structure extends the need of fixed movement of labor and technical resources of considerable distances, creations of extended temporary engineering networks and fixed repeating of standard technological transactions. All this creates high-quality prerequisites to forming of the line organization of works.

The most characteristic representatives of LES are tunnels and lines of the subway. The specific technology requiring the application of a certain difficult technique and high qualification of contractors is applied to a construction of tunnels and lines of the subway. The research showed that methods of designing are carried out, and specific constructive decisions are applied.

Investment projects on a construction of LES belong to the most difficult and large-scale construction projects, characterized by the high cost and the considerable duration of the construction phase proceeding decades. At the same time, the duration of the functioning of subway constructions and tunnels are up to hundred years require an unconditional ensuring high reliability and safety of operation of an object. The accomplishment of these requirements is in turn possible only in the case of high quality of project developments, the accurate accomplishment of an investing program and the high-quality organization of all production process.

Different types of resources are involved in modern conditions in a construction of such difficult objects as linearly-extended constructions; the large number of specialists, machines, mechanisms and the equipment are busy. By the numerous researchers [1 - 4] it is proved that the greatest opportunities of increase in efficiency of a construction of similar objects are connected with need of increase in organizational and technological reliability – capabilities of organizational, technology, management and economic solutions on providing with a certain probability of achievement of the set (rated) result of functioning of construction systems in the conditions of accidental indignations inherent in them.

In works [5, 6] the organizational and technological reliability (OTR) is considered as complex property of an object and is presented in the form of the complete interconnected and complementary structure - it is divided into two hierarchy levels:

1) Control level - this is the problem of formation and studies in the three-dimensional model display state of the control object as a whole;

2) Independent level - is to provide solutions to problems of the first level which include issues related to risk management, organizational problems and problems of the feasibility of construction projects [7, 8].

Ensuring a high growth rate of LES readiness at the lowest rate of consumption of all types of

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resources requires the development of highly efficient construction plan and continuous control action in the course of the production process. At the stage of planning the construction of LES, there produced the collection and processing of information, the study of possible options for planning decisions; evaluate the options and select the best, detailing the decision on the time and the performers [9,10] . At the same time, possible risks are taken into account at the planning stage both jeopardizing the scheduled progress and the possible impact of the external environment, causing deviations and delays in the implementation of a number of works. This approach can significantly improve the reliability of the implementation of the plan calculated [11, 12].

However, despite the measures taken to improve the reliability targets, the impact of various random environmental factors, delays in the delivery of construction materials and often lead to the breakdown of the planned timing of the stages of construction. In some cases, the timing failures are on such a scale that the output in the future for the planned operation becomes impossible to complete the construction of the LES in the approved time. The objective of a timely response to the emergence of dangerous failures and the development of operational management decisions that ensure the planned completion of the construction [3].

Control solutions may be to clarify and change the individual elements of the plan, the additional degree of saturation of the resources of production, the application of new technologies and effective methods of work organization. If serious deviations from the planned pace of construction may be necessary to complete redevelopment of the sequence and timing of milestones. In some cases, it requires the adjustment of certain planning decisions for an additional economic benefit.

2. Materials and methods

In each control loop to eliminate the arisen four specific periods of failure can be identified:

- The period of data collection, processing, analyzing information and identifying the presence of faults, delays, and gaps;
- A period of development, formation, and specification of management decisions, transfer and bring solutions to the performers;
- The period of implementation of management decisions, the transfer of elements of the production process to the new scheme of work, monitoring the progress of the implementation of decisions;
- The period of the free flow of the production process in the new scheme of work after the implementation of management decisions.

Accordingly, the duration of the control cycle is determined by the duration of the period under review:

$$T_{inf} = t_{inf} + t_{sol} + t_{per} + t_{sv}, \quad (1)$$

where

t_{inf} – the first period of data collection and processing of information;

t_{sol} – the second period of the development of control solution;

t_{tr} – the third period of transition to the production of a new scheme of work on the managing decision;

t_{fr} – the fourth period of the free flow of production.

Some possible issues that could have a serious impact on the course and the pace of construction, it is possible to assess and predict in advance of their occurrence.

As predicted disturbances and problems in the majority of cases can be considered as potential breakdowns and delays which in their development can have a significant impact on the manufacturing process, at each stage of construction it is advisable to carry out the analysis of possible violations and to develop the necessary compensatory measures.

The identity of the projected disruptions, disturbances, and delays, assessment of their impact on turnaround time, pre-development of possible management decisions and the implementation of additional measures could significantly improve the reliability of the received LES construction plan.

Projected and estimated violations and delays can have a chance to go into the general stream of violations and delays the impact of which is also probabilistic in nature. However, the probability of their occurrence and the impact is much smaller than the usual random disturbances and delays. The probability of occurrence of all types of violations and delays can be estimated from the Poisson function [13].

The expected volume of construction works, the failure of one control cycle because of the projected impact of disturbances and delays, it can be expressed as

$$V^1_{nev} = \sum_{i=1}^{\lambda_f} \Delta_{red} \cdot p_i \cdot \left(t_{inf} + t_{sol} + t_{per} \right)$$

where p_i – the likelihood of the impact of i-projected violation;

λ_f is the flow forecast parameter violations;

Δ_{red} is the value of reducing the rate of construction in the unit of time for the i-th violation.

The expected volume of installation and construction works, outstanding for one cycle of management because of impact of casual violations and delays, it can be expressed as:

$$V^2_{nev} = \sum_{i=1}^{\lambda_f} \Delta_{red} \left(t_{inf} + t_{sol} + t_{per} \right)$$

Then the volume of construction works executed in one cycle management, taking into account the impact of all types of violations and delays can be determined from the expression

$$V_{man} = g^P \cdot T_{man} - V^1_{nev} - V^2_{nev} .$$

Factually accepted rate of performance of installation and construction works considering the influence of all types of casual violations and delays compensating their influence for increase in reliability of planned targets can be presented by the expression:

$$g^F = g^P \cdot g^P \cdot T_{pl} \Big/ \sum_{f=1}^{F} V_{man\ f}$$

Where F is the management cycles quantity for the entire period of construction T_{pl};

g^P is the planned speed of construction of LES;

g^F is the factual accepted speed of construction of LES.

Considering the organizational and technological reliability as probability of completion of an asset construction of LES in the terms established by the schedule in case of accomplishment of the planned amount of works, it is possible to accept normal distribution of dispersion of the accomplishment amounts:

$$P\left(V_1 \le V_{pl} \le V_2\right) = \left(1/\sqrt{2\pi}\right) \cdot \int_0^{V_2 - V_{pl}^2/2} e\,dx \; - \left(1/\sqrt{2\pi}\right) \int_0^{V_1 - V_{pl}^2/2} e\,dx$$

where $P(V_{pl})$ – the probability of the planned volume performance of the installation and construction works (ICW) for an established period T_{pl};

$$V_{pl} = g^P \cdot T_{pl}\ ; \quad V_1 = \sum_{f=1}^{F} V_{man\,f}\ ; \quad V_2 = g^F \cdot T_{pl}\ .$$

Possible impacts of violations and delays have a significant effect on the reliability of construction plans implementation of objects on the course of production processes. Therefore maintenance of a necessary level of reliability requires a certain amount of costs of financial and technical resources. Besides, the choice of cost-efficient methods needs to be approved with optimum terms of a construction of LES.

One of the main directions of increase in reliability and stability of plans is the forecast analysis of all types of violations and delays, assessment of all depth of their impact on the process of construction of LES and development of the measures providing neutralization of perhaps bigger number of dangerous failures. Generally, violations and delays shall come to light at early stages of their development that require the organization of work of governing body in the monitoring mode.

As shows the analysis of the process of a construction and management, the most effective method of increase in reliability of uniform and timely accomplishment of installation and construction works is the preservation of material resources and completion dates.

Less known and seldom applied method is reservation of technology of performance of works and the organization of works. These methods consist in plan development of the provided earlier alternative options of technology and the organization of accomplishment of the most labor-consuming installation and construction works. Development of such plans is a labor-intensive process but does not require considerable additional resources.

3. Results and Discussion

LES in the form of tunnels and lines of the subway are objects which construction is performed on the basis of the application of a specific and difficult technique in rather constrained conditions. To different types of tunnelling works requirements for the safety of the performed works are shown the raised one in comparison with regular technology. Increased requirements are connected also with considerable difficulties of production construction, assembly and balancing, and commissioning. Difficulties of works arise because of the following specifics of the device of tunnels and underground developments:

1. Development of a face and the device of tunnels are made using difficult technical devices and is connected with high requirements for safety of conducting works;

2. Accomplishment of construction works (installation of lining, solution forming, stamping of seams, etc.) is made after completion of passing works in the constrained conditions;

3. The Installation and Construction Works (ICW) differ in high complexity and labor input in case of strict requirements on quality of accomplishment and ensuring the reliability of designs with multistage control by various devices and the equipment.

4. A Dense combination of driving and construction works and works on the installation of the types of the equipment at all stages of the device of tunnels and lines of the subway is required.

5. The considerable amount of special work types is made (a driving in difficult hydrogeological conditions, freezing of soil, a construction of underwater tunnels, forcing of gravel and solution for the lining, etc.).

Development of technology for the construction of tunnels of the function is performed in many countries in the directions of essential reducing terms of a construction in case of minimization of cost indicators. Increase in efficiency of technologies of a construction of tunnels at the present stage is performed by application of multiple technological schemes, a decrease in power consumption and a material capacity, implementation of the high-mechanized complexes and specialized driving combines providing the high speed of a driving.

Thus, work of governing body should base taking into account the principles of the reliability of construction processes. At the same time, management efficiency depends on costs for the achievement of required rated level of reliability.

Regulation is understood as the establishment of the specifications and technical documentation of requirements to reliability. Regulation of reliability includes the choice of product indicators, the feasibility statement on measure values of the reliability of an object and its components [14].

Costs for maintenance of rated level of reliability consist of costs for reservation of material resources – C_r, on the reservation of terms of the work performance $-C_{rter}$, on the reservation of technology $-C_{tech,}$ and organizations of works $-C_{org}$.

$$C_{rlr} = \sum_{j=1}^{m}\left(C_{r\,j} + C_{rter\,j} + C_{tech\,j} + C_{org\,j}\right)$$

Where is the type of works at which reservation is made;

M is the quantity of the considered types of works.

Ensuring the necessarily rated level of the organizational and technological reliability (OTR) considerably becomes simpler in the case of preliminary acceptance of necessary measures on the basis of short-term forecasting of the development of production processes. Assessment of the forthcoming development of the process of a construction of LES with ensuring the OTN new level requires consideration of certain parameters and indicators. It is necessary to carry an assessment of the possible delays and failures which are easily predicted on a condition of the providing processes and also an assessment of the frequency of emergence and force of impact of accidentally arising violations and delays in production to highlights of assessment of the forthcoming development of production. Another important point of assessment of production is the growth of readiness of an object and compliance of speed of construction to planned targets.

For a certain period of time, it is possible to apply mathematical model of a type to assessment of frequency of emergence of violations and delays

$\lambda t = \gamma t + \varepsilon t$,

where λt is the number of violations and delays during the time t;

λ is stream parameter – average of the requirements arriving in a unit of time;

γt is the number of the violations and delays accepted for the period t considering for the previous periods;

εt is casual independent deviations with an average value equal to zero.

It is necessary to accept time period for determination of an average number of violations and delays equal to the duration of a cycle of management. In turn duration of a cycle of management has to allow estimating the arisen violations and delays. Then the expected number of violations and delays for the forthcoming next cycle of management $\lambda t_{man}(T)$ is defined on the basis of a numerical number of violations and delays (S(T) assessment) which have arisen during T on each cycle of management t^1_{man}, t^2_{man}, ..., t^a_{man} by calculation of the exponential average size:

$S_i = \alpha\lambda_i + \beta S_i - 1$;$S\ (T) = \alpha\cdot\lambda\ (T) + \beta\cdot\ S\ (T-1)$, where $\beta = 1 - \alpha$. (10)

For a certain period of time, it is possible to apply mathematical model of a type to forecast the growth of amount of readiness of LES

$Gt = \Omega^1 + \Omega^2 \cdot t$,

Where Gt is the volume of readiness of an object on time t;

Ω^1 and Ω^2 are the coefficients of growth of readiness of an object defined on the basis of the planned rate of the work performance.

Due to the organization of work of governing body in the cyclic mode of development of the operating decision, it is also expedient to control readiness of LES on time spans T_{man}. The received time number of growth of an object readiness can be used for forecasting of the course of a construction and assessment of the effectiveness of measures for maintenance of the set reliability level. For receipt of projections, it is necessary to carry out exponential smoothing to receive the model approximating a trend. The expected value of readiness G in timepoint T + τ , where the time of anticipation of 2 or 3 size T_{man}, can be determined by the expression

$$G(T+\tau) = \Omega^1(T) + \Omega^2(T)\cdot\tau = \left[2 + (\alpha/\beta)\cdot\tau\right]\cdot S(T) - \left[1 + (\alpha/\beta)\cdot\tau\right]\cdot S(T)^{[2]}$$

where:

$$\Omega^1(T) = 2S(T) - S(T)^{[2]}; \qquad \Omega^2(T) = (\alpha/\beta)\cdot\left[S(T) - S(T)^{[2]}\right];$$

$$S(T) = \alpha\cdot G(T) + \beta\cdot S(T-1); \quad S(T)^{[2]} = \alpha - S(T) + \beta\cdot S(T-1)^{[2]}.$$

Short-term forecasting in the case of a construction of LES allows to determine key parameters of key parameters production of a management activity. The forecast of the expected violations number in production delays on (10), determines duration of a cycle of management and possible actions of governing body, and also increases reliability of the planned targets accomplishment. The forecast for growth rates of readiness of an object on (12) allows to perform reasonable reservation of resources and terms of works. The considered approach by calculation of projections gives the chance to make the forecast for other parameters of a construction, such as dates of termination of the main works, performance of the main divisions, and in the presence of a number of estimates of reliability the forecast and for reliability indicator.

In the conditions of a construction of the linearly-extended structures (LES) application of the following approaches to improvement of indicators of reliability is possible:

- Forming and implementation of methods of the organization of works, the most reasonable for reliability indicators;

- Development of methods of creation of float times and resources as a part of the planned and managing decisions promoting an increase in the level of reliability;

- Forming a part of planned and managing solutions of duplicative methods of the organization and technology of accomplishment of separate complexes of the works providing observance of the accepted reliability indicators;

- Creation of the management system construction production providing continuous monitoring of a work flow and timely response to deviations from the accepted planned targets of reliability;

-Development of planned and managing decisions taking into account compensation of possible external impacts for an increase in the level of reliability.

Implementation of the considered approaches on the increase in the organizational technological reliability (OTR) requires the solution of two enough complex theoretical problems. Development of assessment methods of the probability of accomplishment of the made planned and managing decisions for specific acceptance of an increase in reliability belongs to the first problem (a method of the organization of the job got float times and resources, the created duplicative chains of works, a management structure, etc.) The second at least complex problem is reliability level assessment in case of combined use of several methods, each of which makes the specific contribution.

The important and complex problem is the efficiency evaluation of the made decisions on construction OTR linearly - extended structures. As a performance indicator of OTR growth of level of reliability, an increase in efficiency of the construction process, cost reduction on the organization of a construction of LES, can be used.

One of the most important methods of increase in OTR is forming of effective methods of the organization of works. In the case of a construction of lines of the subway, the closed method in the form of tunnels and an open method of lines and stations should be considered the most effective line methods of the organization of works [15]. Their great variety and diversity of the models are used to calculate and optimize the organization of work requires a detailed study of emerging opportunities.

Another important area of improving the reliability implementation of LES construction plans is the creation of reserves of time and resources. Time reserves of works are formed by applying the method of the critical path, as well as limiting the saturation of work resources.

A powerful way to improve the reliability of the developed planning and regulatory decisions is the duplication of the most important inter-related works (chains). Duplication can be done from the standpoint of the organization of work and from the standpoint of implementation of group work techniques. Duplication from organization positions allows in case of complications, such as with fronts of work, transfer manufacturing process to another chain to solve complications without reducing pace and reliability. From the standpoint of technology duplicating chain of works allows to replace the technical and labor resources to other systems on the other technologies also without reducing the pace of work and level of reliability.

In addition to the considered ways of improving the reliability of plan and regulatory decisions the impact of the external environment should be taken into account. The effects are random in both frequency and magnitude of the impact on the development of the production process. Manufacturing process development forecasting allows to develop the necessary measures in advance and to a large extent reduce the impact on the pace of work and the level of OTR.

Increasing the OTR in the development and implementation of design solutions requires some additional expenses but it leads to certain positive results. Additional expenses arise in the field of management in the course of a detailed study of planning decisions, additional resources and regular monitoring of the production costs and operating decisions. Positive economic results emerge in the field of construction industry in the following areas:

provision of usually early completion of the construction or complex of works;

cost reduction due to downtime, for performance of a rush job and excessive labor and technical resources.

Considering reliability as the probability of performing complex in the planned terms U, it can be written at higher level OTR

$U = \varphi(p, \Sigma P_i, \Sigma T_i, \Sigma D_i, \varepsilon)$,

i.e. the reliability is some functional dependence on overall probability (p) of the implementation of this complex of work, aggregate potential reserves of various kinds of resources (ΣRi), the aggregate of envisaged reserves of time for a range of of work (ΣTi), aggregate duplicating chains of work (ΣDi) and the control system operation scheme (ε). The whole experience of the construction of any facilities including LES, as well as numerous studies [16 and others] indicate the presence of such a relationship.

The ultimate goal of improving reliability is to reduce overall costs and achieve economic efficiency.

In a simplified version management efficiency can be determined from the ratio

$$E_c^m = C_m^{mc} / G^f$$

where

C_e^{mc} is management costs for cost estimates;

G^f is the factual volume of construction and installation work (an object readiness).

Along with the above carried out studies to assess the impact of the volume of backup (time and resources) on the reliability of schedules show that in addition to the calculated according to known methods probability it is necessary to consider a number of additional parameters [3]. These indicators should include:

- the volume of reserves of time in non-critical paths, chains of work or private flows (ΔTtr_i);
- the volume of reserves of time for completion of the directive work deadlines, paths and private flows ($\Delta Tcom_i$);
- quantitative expression of reserves by the values assigned priorities for the work complexes and private flows (ΔPr_i);
- the volume of reserves of labor and technical resources for the complex of works and private flows (ΔB_i, ΔA_i);
- the volume of reserves of material and financial resources for complexes of works and private flows (ΔM_i, ΔF_i).

In accordance with the approach of estimating the probability of the term of implementation of the work on the schedule developed considered indicators ΔTrv_i ΔTok_i, ΔPr_i, ΔA_i, ΔV_i, ΔM_i, ΔF_i do not have a direct and measurable impact. Undoubtedly, in the development of estimates of the duration of each activity, some indicators are taken into account partially, but further calculations are made on the obtained probability density function, and they do not affect the final estimates. However, considered indicators are very important for assessment of the reliability.

Since reliability is determined in the main part of the probability compliance with established indicators of the plan, additional considered indicators in terms of reliability can also increase the probability of settlement. For the account of additional increase in probability as a result reservation time and resources there are no specific calculation methods in the scientific literature. In our opinion, the first thing to do is to consider the volume of a reservation for each proposed indicator. Since indicators have the combined effect on the probability, it is necessary to take into account the total amount of reserves. In this case the following average figure can be offered;

$$U_x = \Big[\sum_{i=1}^{n}\sum_{j=1}^{m} \Delta T^{P}_{rvij} \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} t^{P}_{ij} + \sum_{j=1}^{m}\left(T^{D}_{\text{ок} j} - T^{P}_{\text{ок} j}\right) \Big/ \sum_{j=1}^{m} T^{D}_{\text{ок} j} + \sum_{i=1}^{n}\left(T^{D}_{\text{ок} i} - T^{P}_{\text{ок} i}\right) \Big/ \sum_{i=1}^{n} T^{D}_{\text{ок} i} +$$
$$+ \sum_{i=1}^{n}\sum_{j=1}^{m}\left(Pr^{P}_{ij} - Pr^{P}_{ij}\right) \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} Pr^{P}_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m}\left(A^{P}_{ij} - A^{D}_{ij}\right) \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} A^{P}_{ij} +$$
$$+ \sum_{i=1}^{n}\sum_{j=1}^{m}\left(B^{P}_{ij} - B^{D}_{ij}\right) \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} B^{P}_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m}\left(M^{P}_{ij} - M^{D}_{ij}\right) \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} M^{P}_{pij} +$$
$$+ \sum_{i=1}^{n}\sum_{j=1}^{m}\left(F^{P}_{ij} - F^{D}_{ij}\right) \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} F^{P}_{ij} \Big] \Big/ 8$$

The following designations are accepted:

n and m – size of the matrix, which characterizes the mainstreaming work, where n- number of types of work and private flows, and m - number of private work fronts (bays, parts of buildings;

ΔT^{P}_{rvij} is reserve time in i-type work for the j-private front, which indicates the possibility of extending or offset this work without increasing the total time for completion of the entire flow of the subject schedule;

t^{P}_{ij} is duration of the work of i-type adopted on the considered schedule for the j-particular front;

$T^{Д}_{\text{ок} j}$, $T^{П}_{\text{ок} j}$ are required (directive) and the planned deadline for all the works at the j-front;

$T^{D}_{\text{ок} i}$, $T^{P}_{\text{ок} i}$ are required (directive) and the planned completion date of i-type works at all m-fronts;

Pr^{D}_{ij}, Pr^{P}_{ij} are set (directive) and adopted in the schedule priority value for the i-type of work at the j-private front.

Other parameters have the same meaning for the planned flow.

Formed average figure Ux very accurately describes the effect of reserves of time and resources to enhance the probability of execution schedules within the required time. Therefore it is possible to offer the following dependence to estimate the probability of implementation of the plan adopted in time.

$P^{rv}(T_{pl}) = p(T_{pl}) \cdot (1 + \zeta \cdot U_x)$, (18)

where ζ – the average level of indicator influence on the value of the probability indicator (usually ζ = 0,7 - 1,0).

In general, to increase the reliability of planning and control solutions in the construction of linearly extended constructions a number of areas have been addressed among which as the most important may be considered:

–selection of special methods of formation of the organization of work and the construction of calendar plans;

–reservation of time and resources in the formation of the organization and building technology, and in the construction plans;

–building control system adequate for the development of production processes.

Implementation of these directions requires the use of methods of assessment of the probability and level of organizational and technological reliability for concrete plans, as well as evaluating the effectiveness of the decisions taken in view of the normalized level of reliability.

The most effective methods of organizing LES construction should be considered the group of straightline methods [16].

3. Theoretical and practical implications

Theory and practice of building linearly extended objects requires evidence-based planning of construction and tunnel works, ie selecting among the possible options for the most efficient and appropriate production. First of all, plans should ensure the continuity of the implementation of adopted performance and reliability of their achievements. If necessary, the plans should allow a adjustments and change some of the parameters in the process of their implementation and manage any perceptible change in outcome.

Two most frequent variants of planning are used in the world practice. In the first variant strict plans are developed for established planning periods, usually for one year. With such a rigid system with clear criteria for planning and performance for a certain period, the conditions for stability of the production work are created. However, in case of violations of the plan there is a risk of delayed accounting changes and disruption of the established indicators.

According to the second variant flexible scheduling is carried out, which allows to change the value of the performance as changes in the work situation appear. Such planning allows for a flexible response to the progress of the work, but there are no clear stable value targets. As a rule, flexible planning is use when there is certain instability of financial resources and technical means.

Western construction firms prefer a combination of hard planning with flexible adjustment plans in the course of their performance. This combined approach combines the advantages of rigid and flexible planning systems, but inherent in these systems deficiencies continue have a negative impact. Therefore, improvement of planning methods require further research and development.

Formation of a sustainable plan to achieve high efficiency of the accepted values of indicators and quality of investments is possible with the help of scheduling models. Scheduling allows the timing and sequence of construction sites, buildings and structures, as well as the sequence and duration of the work complexes on each structure. In models of scheduling during plans development, a significant number of different parameters, constraints, and their quality assessments are taken into account [1].

High efficiency and reliability of the timely implementation of a range of works on the linearly extended constructions provided with carefully designed calendar plan of their construction. In drawing up the construction schedule of the construction or performance of a complex of various works, to improve the effectiveness of both the planning phase and phase control, it is necessary not only to achieve a reduction in construction time limit, but also to minimize the need for labor and technical resources. Currently available techniques and methods for appointment of labor and technical resources to consider various indicators, criteria and factors, but do not take into account the effect of the timing and sequence of construction on the reliability of the developed schedule of works [10]. However, the schedule of work has a decisive influence not only in terms of construction and reliability of compliance of appointed time, but also on the efficient use of all resources.

Reduction of terms of construction and improvement of technical and economic performance calendar plan is advantageously carried out simultaneously with the calculation of required labor and technical resources, the search of a rational layout, calculating the optimum order of execution of works, calculating the reliability of the developed plan. When forming the calendar plan during the LES construction the full implementation of the production organization of work can be applied, which ensures high efficiency of the construction process. Existing methods of forming straight-line organization of works on the LES construction suggest solution for considered problems only at certain stages of the application and only under individual methods without consideration of all possibilities [9, 15].

To achieve the highest possible efficiency and sustainability of calendar plans it is advisable to highlight the most important indicators and to define the general criteria for the search for the most rational variant of construction. Necessary indicators are worth to take into account in the form of restrictions on the formation of a defined values. Then, the control process will be formed based on the calendar plan and strive to ensure the smallest possible deviation from the defined values of the indicators.

Formation and optimization of calendar plans of LES construction, taking into account the impact of all the above factors and taking into account the achievement of rational values of the main indicators, high stability of the control process plans is a very complex and time consuming task. Solution of this problem is possible on the basis of economic and mathematical model, when the indicators of efficiency will be included in the objective function, and other parameters and requirements will be reflected in the composition of various constraints [6].

The operation of any control system is aimed at achieving targets and solving set problems. During the LES construction, the main purpose is managing the commissioning of tunnels and underground lines with a maximum degree of safety of operation with a high level of quality and reliability. This management should ensure the achievement of high performance not only of the object under construction, but of the construction industry as a whole. Construction industry is a dynamic and evolving self-governing system. Dynamic industrial construction system arises due to continuous changes in the conditions of the production processes and continuous exposure to the external environment.

The control system includes a control body (the subject of management) and controlled subsystem (object of management). Between the subsystems (the object and the subject of management), there is some interaction, which is realized by direct connections and feedbacks. At the same time object and subject of management can have quite a complex organizational structure, which is based on the levels of the hierarchical chain of command. Functioning construction organizations have different divisions and units, to which in varying degrees are subordinated production workshops, laboratories, supply units, construction crews and others.

Management bodies are fully, partially, or individual units to specialize in areas of administrative activity:

- by function - planning, organization, management;
- by time feature - prospective, current, operational management;
- by constituent elements of the construction process of LES are provision of design and estimating of documentation, provision of equipment, the production of mounting works, mining works, etc.;
- the stages of construction - site preparation, sinking a vertical shaft (trunk) and horizontal tunnels, construction of building structures, object delivery;
- information, development of control decisions, transmission and storage of information, and others.

Performing these tasks requires an appropriate construction of the structure of the management subject. Management structure is a specific form of the division of labor in the management system, promotes the release of relatively stable areas of administrative activity. Kind of such activity is usually determined as a management function. The number of usually considered management functions ranging from a few units to a few dozen. Researchers of management activities consider management functions in several directions.

In the first direction, management functions are considered as the controls that are covered by the organization and structure of government. These management functions include executive management, selection and placement of personnel, general office work etc.

The second direction may include management functions, which are considered as tasks or activities of government.

This refers to the activities of governing bodies in areas of the production process. The structure of such management functions include the organization of payroll, procurement, building maintenance, standardization and normalization, etc.

The other direction include functions related to the general stages of the management cycle without regard to the specific tasks and structures. The structure of such management functions include data collection and processing, production management decisions, control over the execution of decisions etc.

Additionally, it is possible to select the direction for the management functions related to the implementation of the whole process of construction of any facilities, including LES. This includes the organization of the design process, construction financing, contractual work with other organizations, work with supervisory authorities etc.

Construction companies in the construction of LES interact with many participating organizations. Some organizations operate as subordinate structures, other organizations participate as co-executors that implement certain types of work, and some organizations are acting as a regulatory and supervisory side. Therefore, the construction of the LES is controlled by bodies with a hierarchical structure, which are located at a certain level of management and carrying out the receiving, processing and transfer of management information.

Considering the whole LES construction management system as a whole, there are the following subsystems:

- production subsystem, which includes all specialized contractors with their governments, technology and production staff;
- providing subsystem, which includes design companies, equipment manufacturers and other suppliers of building materials and constructions;
- management subsystem, which includes urban management Metro construction, key management Tunnel metro construction and management of construction corporations;
- a subsystem safety and reliability of the underground lines, which include environmental security, fire control, technical supervision, local authorities and others.
- financial subsystem, which consists of all investors, banks and other financial institutions.

Improving organizational structures has now become regarded as one of the main areas to improve management efficiency and construction of any facilities, including LES. The need to lift the management level, its efficiency stems from a significant expansion of the volume of construction underground lines and transport tunnels under recurrent economic crisis deepens. Improving the efficiency management of LES construction is possible not only due to the formation of a science-based organizational structures, but also by optimizing the functions performed by management.

4. Conclusion

Methods of solution of certain issues related to the OTR under construction of underground LES, based on the fulfillment of a deep analysis of the current state of the construction of the LES, unsolved problems of constructing sustainable and reliable criteria for planning and management, as well as the financial and economic parameters.

Analytical studies on the selection of scientific and methodical approach to solving the problem, the evaluation highlighted the technological, industrial and institutional settings control subsystems and OTR as a whole, have been carried out with the use of modern provisions reliability theory. The advances in computer-aided design systems, systems engineering, various mathematical methods of including network planning and management, as well as the organization of the line production construction were also used.

The analysis of the current state of construction the LES and the existing planning and management issues, as well as expert assessment with rankings of the most significant factors lead to the following conclusions:

1. Construction of LES is a complex production process, which lead to the creation of a powerful transport complex based on tunneling. This production process involves a high level specialists, installation of complex and largest building structures, installation of modern organized and technically sophisticated power equipment, involves a large number of construction, tunneling and installation specific equipment.

The industrialization of the construction industry is the main direction of technical progress in the construction of the LES. The process of construction of transport tunnels is necessary to turn into the processes of in-line installation of structures and equipment, pre-assembled in large units by forces of factory and contracting specialized organizations. Such process management is possible only with the creation of a highly technological process development and implementation of management decisions.

2. Effective management of construction of transport tunnels and stations requires the construction of an adequate control system, having a workable governing body. The structure of the management body should have multiple levels in connection with the need to process large volumes of information and rapid response to changes in operating conditions. Management levels are based on the principle of the organizational chain of command and have a hierarchical structure. Governance structure should take into account all the basic functions necessary to implement the management decisions. Therefore, the creation of optimal hierarchical structure of management of the LES construction is impossible without corresponding theoretical developments.

3. Development of planning decisions with high reliability level requires the use of the system of methods that can be divided into two areas - operational and functional. Operating methods for improving reliability ensure the development of planned solutions and their adjustment at the desired level of economic efficiency of building production. Functional methods aimed at preserving by management system the received level of reliability and effectiveness of planning decisions.

4. The system of methods and models of production management decisions can provide effective control authority work in the planning and construction management of LES with high levels of reliability. The duration and content of the periods and LES construction stages should be taken into account in the development of methods and models of production management decisions. Formation of management decisions in the process of creating tunnels should take into account the state of the project development, the level of the tasks of the preparatory period and the combination of the planned phases of construction. An integrated approach to the development of management processes provides the ability to create theoretical foundations of effective management of the LES construction.

Thus, one of the main problems is the creation of sustainable plans and their implementation through the production system and management system at the highest possible level of economic efficiency. It is particularly relevant when creating the LES, which have significant potential for the organization of in-line construction. Inline (conveyor) manufacturing method has the highest productivity and efficiency level, and therefore creation on this basis of planning and management system is very practical.

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