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DEVELOPMENT OF A MONITORING SYSTEM FOR SCHEDULED WORKS AT DISTRIBUTED FACILITIES

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Keywords: monitoring; distributed facilities; resource distribution models.

Abstract: The article considers methods for monitoring progress of the works at distributed construction facilities, as well as for evaluating the state of the transport and technological vehicle pool. Correlations obtained in the course of the study are used in the monitoring system to coordinate scheduled works with resource distribution models. This forms a basis for developing rational methods for performing the aggregate scope of works in the generalized model.

Introduction

Contemporary trends for the implementation of important large construction projects in the Russian Federation and worldwide [1] have their peculiarities in terms of transport support of the work. Efficiency of machinery operation at large and distributed facilities, as well as within large logistic structures supporting construction of several facilities is in many ways deciding for final economic and time efficiency of construction [2]. For enterprises with available fleet of about a thousand vehicles and dozens of serviced facilities, widely spread planning methods have been long recognised inefficient [3]. Even such state-of-the-art approaches as hybrid methods for solving transportation tasks [4], high-quality information support [5], network planning methods and models [6, 7] turn out to be hardly practicable, e.g. due to severe climate conditions [8] leading to reduced technical availability of vehicles, or simply due to complicated organisation of diagnostics, scheduled or emergency maintenance of the fleet. The latter is particularly topical both for Russia, considering high depreciation of vehicles and general quality of Russian cars [3], and globally for any construction site with severe operation conditions. The latter, for instance, include Syria, where significant infrastructure projects are to be implemented in the nearest future [9]. There high temperatures and desert conditions lead to vehicle failures, even if we do not consider other evident dangers, while the distance of the recipient territory from supply sources makes the issue of decreasing counter-productive costs particularly acute. Therefore it is highly important to develop new methods for improving efficiency of transport support of large and distributed construction facilities under conditions of encumbered online diagnostics and maintenance.

The general approach to solving this type of problem is to create a mathematical or transport utilization model and its application to support decision making [10]. However, under the outlined above conditions, the implementation of the model would be extremely complicated. The general approach to solving this type of problem is to create a mathematical or transport utilization model and its application to support decision making [10]. However, under the outlined above conditions, the implementation of the model would be extremely complicated, and it won't have the desired effect when it comes to the transport use decisions.

A multi-agent systems model (**MAS**) is commonly used to minimize the scale of the problem, among other approaches [11]. However, the intrinsic complexity of these models, on top of proving their adequacy and error determination, rules definition of agents' behavior are well known.

In the classical multi-agent system [12], the presence of indicators of the state of objects is assumed. Based on the readings of the indicators, an activity algorithm and a control method are selected.

In the given problem, the indicators are replaced by live information received from people; therefore multiple difficulties arise in decision-making [13].

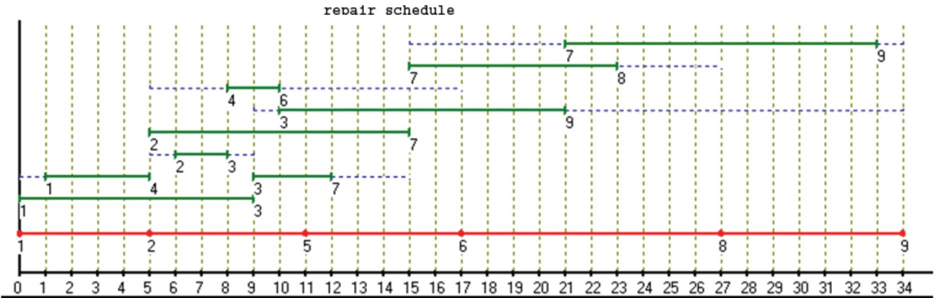
Therefore, it is reasonable to apply one of the basic principles of the system analysis, the transformation of objects to systems, and consistent coordination of their goals, which will allow solving independent problems at each management level.

The definition of methods for the distribution of vehicles over construction sites in this particular way will reduce the influence of the human factor, described above, and achieve a certain increase in the efficiency of the transport use.

Organization of monitoring of scheduled works at distributed facilities

Monitoring will here mean the function of permanent observation of some item, process or phenomenon in order to identify its state and the trends of such state changes, as well as to determine its conformity to the model or initial state. The structure of the monitoring process described in scientific literature can be represented as a sequence of three major stages: setting of monitoring goals; selection of monitoring objects; forming of individual tasks.

The main objective of project implementation control (Fig. 1) is to get the planned level of profit, which is ensured by observing the set prime cost of the works, their deadlines and by minimizing additional expenses for elimination of defects [14, 16].



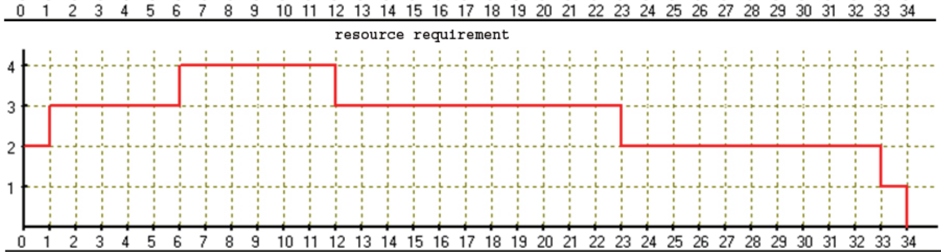


Fig. 1. Interconnection of stages of the network resource distribution model

In general the deviation from planned direct costs in month *i* with respect to work *j* can be calculated as follows

$$\Delta_{i,j} = \sum_{\hbar=1}^{\mathrm{p}} C_{ij}^{k} (q_{ij}^{k} - \bar{q}_{j}^{k}) + \lambda_{ij}\,, \tag{1}$$

where q_{ij}^{k} is actual consumption of resource *k* (equipment, materials, labour) in month *i*; $\bar{q}_{ij}^{k}$ is actual consumption of resource *k* provided for at the time of contract conclusion (with respect to the work scope performed in month *i*); C_{ij}^{k} is price (rate) of resource *k* in month *i*; λ_{ij} is expenses for eliminating defects in work *j* per month *i*.

Total deviation Δ for the project makes $\sum_{i=1}^{m}\sum_{j=1}^{n}\Delta_{ij} \pm S$, where *m* is total duration (months) of construction and installation works, n is the quantity of works performed with own resources (if work *j* is not carried out in month *i*, $\Delta_{i,j} = 0$); *S* is the bonus for ahead-of-schedule facility completion (or penalty for delayed construction). In the context of inflation it is expedient to calculate deviations $\Delta_{i,j}$ in comparable prices.

According to the western practice, main responsibility for the contract budget is borne by the project manager [15]. Besides, they have all necessary powers (technical procurement for the construction site, including lease of equipment, purchase of materials and structures, hiring of labour, selection of subcontractors). Project manager together with his/her team (section managers – foremen, estimators) continuously (daily in certain cases) monitors the works progress and resources consumption. In case of significant deviations he/she takes immediate active organizational and technical measures (if central office assistance is required, project manager acts in contact with the contract department director) [16]. In the west, staying within the contract budget and works deadlines are the major criteria of the project manager's success. It is necessary to mention that the manager always participates in preparing the tender bid (programme and deadlines, unit prices) and is therefore jointly (with the planning and cost estimate department) liable for the planned contract budget.

Competitive ability of a company largely depends on the prime cost of construction and installation works as compared with the branch average level. Thus, it is recommended to use the following correlation as a basis for comparative analysis of unit prime cost of the work (direct expenses)

$$\Delta = \left(\sum_{i=1}^{m} q_i c_i - \sum_{i=1}^{m} q_i^0 c_i^0 \right) \Bigg/ \sum_{i=1}^{m} q_i^0 c_i^0\,, \tag{2}$$

where q_i and q_i^0 are individual and branch average resource consumption rates for the type of construction and installation works under consideration respectively, while c_i and c_i^0 is individual and normative budget prices (rates).

Calculation according to correlation (2) demonstrates by how many percent individual prime cost of the works is higher (lower) than the branch average one. For a more profound comparative analysis it is necessary to understand the reasons for deviation of individual prime cost from the average level. With this view it is proposed to use the following criterion

$$\Delta = \Delta_{\mathrm{eq}} + \Delta_{\mathrm{m}} + \Delta_{\mathrm{s}}\,. \tag{3}$$

Deviation in terms of expenses for equipment (including energy resources consumption and operators' wages) makes

$$\Delta_{\text{eq}} = 100\left(\sum_{i=1}^{m_1} q_i c_i - \sum_{i=1}^{m_1} q_i^0 c_i^0\right) \Bigg/ \sum_{i=1}^{m} q_i c_i \ . \tag{4}$$

Deviation in terms of expenses for materials and structures makes

$$\Delta_{\text{m}} = 100\left(\sum_{i=m_1+1}^{m_2} q_i c_i - \sum_{i=m_1+1}^{m_2} q_i^0 c_i^0\right) \Bigg/ \sum_{i=1}^{m} q_i c_i \ . \tag{5}$$

Deviation in terms of workers' wages makes

$$\Delta_{\text{s}} = 100\left(\sum_{i=m_2+1}^{m} q_i c_i - \sum_{i=m_2+1}^{m} q_i^0 c_i^0\right) \Bigg/ \sum_{i=1}^{m} q_i c_i \ . \tag{6}$$

Values Δ_{eq}, Δ_{m} and Δ_{s} show the impact of deviations in terms of expenses for equipment, materials and wages on the total prime cost deviation. In their turn they can be decomposed into two components: resource one and price one. Thus,

$$\Delta_{\text{eq}} = \left(\sum_{i=1}^{m_1} q_i c_i^0 - \sum_{i=1}^{m_1} q_i^0 c_i^0\right) + \left(\sum_{i=1}^{m_1} q_i c_i - \sum_{i=1}^{m_1} q_i c_i^0\right) = \Delta_{\text{eq}}^{\text{r}} + \Delta_{\text{eq}}^{\text{w}}. \tag{7}$$

Similarly:

$$\Delta_{\text{m}} = \Delta_{\text{m}}^{\text{p}} + \Delta_{\text{m}}^{\text{w}}, \ \ \Delta_{\text{w}} = \Delta_{\text{w}}^{\text{r}} + \Delta_{\text{s}}^{\text{w}} \ . \tag{8}$$

Calculation of values Δ_{eq}, Δ_{m} and Δ_{s}, as well as their decomposition into resource and price components allows to draw up the guidance for improving competitive ability of the company's unit rates.

If $\Delta_{\text{eq}} > 0$, at $\Delta_{\text{eq}}^{\text{r}} < 0$, it is an evidence of technical underdevelopment and the necessity to upgrade equipment.

If $\Delta_{\text{eq}} > 0$, at $\Delta_{\text{eq}}^{\text{r}} \geq 0$, it means that machinery is not rationally used.

If $\Delta_{\text{eq}}^{\text{w}} \geq 0$, it means that materials and structures are used inefficiently, which can be caused by low level of labour management, lax control of material consumption, outdated technical facilities.

When $\Delta_{\text{eq}}^{\text{w}} < 0$, it is possible to speak about irrational procurement policy [17].

Correlation $\Delta_{\text{s}} > 0$, $\Delta_{\text{s}}^{\text{w}} < 0$ testifies low qualification of workers, accounting for labour intensity of construction and installation works.

Correlation $\Delta_{\text{s}} > 0$, $\Delta_{\text{s}}^{\text{w}} \geq 0$ means bad labour management and an inefficient remuneration system.

Thus, the purpose of comparative analysis of direct expenses for construction and installation works is to develop a system of organizational, economic and technical measures aimed at reducing the prime cost and its components. The impact of such measures can be followed by the dynamics of values Δ, Δ_{eq}, Δ_{m} and Δ_{s}.

A considerable role in forming prime cost of construction and installation works is played by overheads. New cost estimation norms imply determining differentiated standards of overheads for different types of construction and installation works (per one rouble of main workers' wages). These standards can also be used for comparative analysis of overheads level. In such case it is recommended to calculate the deviation from the "normal" level as follows

$$\Delta h = Hf - \sum_{i=1}^{n} H_i^0 A_i \ , \qquad (9)$$

where Hf is actual overheads of the company (absolute value); H_i^0 is branch average standards of overheads for construction and installation works type *i* performed by the company; A_i is wages of main workers engaged in performance of work type *i*.

If $\Delta h > 0$, the company is overspending for overheads, and individual standards (for all types of work) shall be increased in comparison with the branch average standards proportionately to the value of $\gamma_h = Hf \Big/ \sum_{i=1}^{n} H_i^0 A_i$, which has to be considered in comparative analysis of full prime cost of works.

Conclusion

If overspending for overheads is covered by general saving on direct expenses, it is possible to say that the company management system is efficient enough and additional overheads are principally reasonable, though their potential decrease cannot be excluded. If overspending for overheads is accompanied by overspending for direct expenses (or saving on direct expenses is low), it is an evidence of a clearly irrational organization and management structure of the company and the need for its reorganization.

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Построение системы мониторинга выполнения плановых работ на распределенных объектах

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Ключевые слова: модели распределения ресурсов; мониторинг; распределенные объекты.

Аннотация: Рассмотрены средства мониторинга хода выполнения работ на распределенных объектах строительства, а также оценки состояния парка транспортных и технологических машин. Полученные в работе соотношения используются в системе мониторинга для согласования плановых работ с моделями распределения ресурсов, что в рамках обобщенной модели дает основу формирования рациональных механизмов выполнения общей совокупности работ.

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Aufbau eines Überwachungssystems für geplante Arbeiten auf verteilten Objekten

Zusammenfassung: Es sind die Mittel der Überwachung des Fortschritts der Arbeit auf verteilten Bauobjekten sowie der Bewertung des Zustandes des Fuhrparks von Transport-und technologischen Maschinen betrachtet. Die in der Arbeit erhaltenen Verhältnisse werden im Überwachungssystem verwendet, um die geplanten Arbeiten mit den Modellen der Ressourcenverteilung zu koordinieren, was im Rahmen des generalisierten Modells die Grundlage für die Bildung von rationalen Mechanismen der Ausführung der Gesamtheit der Arbeiten bildet.

Construction d'un système de surveillance de l'exécution des travaux planifiés sur les sites distribués

Résumé: Sont examinés les moyens de surveillance de l'avancement des travaux sur les objets de construction distribués ainsi que l'évaluation de l'état du parc de véhicules et de machines technologiques. Les ratios obtenus sont utilisés dans le système de surveillance pour aligner les travaux planifiés sur les mécanismes d'allocation des ressources, ce qui, dans le cadre d'un modèle généralisé, constitue la base de la formation des mécanismes rationnels pour l'exécution de l'ensemble des travaux.

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