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ANALYSIS OF THE DECISION MAKING PROBLEM FOR ENVIRONMENTALLY TRANSPORTATION OF CONSTRUCTION CARGO

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Abstract

Minimizing costs associated with work in remote areas, there is a need for transporting the special equipment to perform the work, is an ongoing problem due to the increasing cost of special equipment, the large size of most equipment types and specifics of its delivery on modern roads and highways. The main way to reduce losses and costs is to find the best options for moving equipment and machinery, based on mathematical models that describe the movement process. This paper focuses on this very task. The study formalizes the task of minimizing the losses and costs associated with the delivery of special equipment to remotely located work sites for construction, installation, repair, post-emergency and other works. There is a classification of the problems associated with transporting different types of special machinery, especially handling equipment as the largest and most voluminous types of such machinery. The authors provide the most striking expressions for the losses and costs associated with the transport process. These expressions include four auxiliary functions, which in turn depend on a number of constants and simple functions. They studied the auxiliary functions for the most important application area of the developed model – the construction sector. The work also presents estimates of the values of all the constants that make up the auxiliary functions, as well as expressions for the simplest functions. The resulting formalized problem can be solved through the use of mathematical programming methods.

Keywords: Classification of problems, construction zone, handling equipment, losses and costs, mathematical model, transport of special equipment

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1. Introduction

Construction operations require many different machines, mechanisms and equipment. They can be roughly divided into the following classes: handling machinery, earthmoving machinery, pile-driving equipment, aggregate processing equipment, equipment for storing, preparing and transporting cement, cement mortar and concrete mixture, machinery and equipment for the construction of cement concrete pavement, equipment for bitumen storage and pumping, for making and transporting bitumen-concrete mixture, machinery for road maintenance and pavement repair and many other types of equipment. We shall highlight the main areas of the work (Mele, 2022; Nikulin, 2023; Rawel, 2022).

One significant technical equipment used in the construction process is the machinery for lifting and moving various construction and other weights at a construction site is handling equipment (HE), which includes a tower, gantry, overhead cranes, winches, conveyors and other machinery. The technical condition of cranes affects not only the proper functioning of construction processes, but also the work safety of operating personnel and workers on site. Many of these facilities are huge, which causes significant problems in transporting them to the construction site and placing them, especially in large cities with often complex transport problems. For the most part, this equipment is very expensive and requires special attention during storage at construction sites. The realities of the Russian industry show that more than two-thirds of cranes and hoists have reached the end of their service life. This creates the challenge of finding the optimum mode of transporting and using these transport facilities, considering the available mix of machinery and equipment, the construction sites and the timetable for each of the sites. There is a great deal of scope for modelling the various processes related to handling equipment (Batayev et al., 2019; Gnedenko et al., 2021).

Another important feature of the construction industry is the importance of transporting construction machinery, loads and materials. Nowadays, road transport handles the vast majority of transportations in the construction sector. The construction industry has developed a wide range of special vehicles for transporting special types of construction loads; in particular, pipe hauliers, cement trucks, concrete mixer trucks, construction panel trucks and others. Thus, the efficiency of both the entire construction industry and the individual construction company depends to a large extent on the efficiency of road transport of construction cargo and materials.

The current situation of the issue of road freight transport, including the construction industry, is reflected in the works of A. V. Velmozhin's Road Freight Transportations; Textbook for Higher Education Institutions, Voytenkov S. S. 'Comparing the results of different technologies of construction cargo delivery in urban areas'.... and others. Research in this field has developed rapidly and very fruitfully in the post-Soviet period. This is reflected in a series of theses and dissertations on this topic, e.g. E. N. Korotkova's Optimization of the Transport Process in the Supply Chain or E. N. Kostyuchenko's Development of the Theory and Practice of Forming Organizational and Technological Construction Systems (Magomadov, 2014a, 2018). But these studies have generally looked at individual narrow problems related to the process of transporting cargo by individual means of transport. There has been no comprehensive, systematic analysis of the problem. We should also note that among the foreign publications on this topic, e.g. Johnson James Wood's Modern Logistics, Williams Publishing 2005, or M.

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Christopher's Logistics and Supply Chain Management, Saint-Petersburg, 2004, there is also no work devoted to a systematic analysis of the problem. Similar problems were considered by E.E. Vitvitsky's Practice of Operational Cost Planning for Cargo Transportation in Cities, Bulletin of SibADI 2012 (Magomadov, 2014b).

The problem of increasing the efficiency of transporting construction materials has always been and still is relevant in all countries. Costs of transportation and handling of these materials have always formed a considerable part of the construction costs: the cost of transport and handling operations makes up 25 and 40% of all construction costs; the construction of one-storey industrial building structures requires on average up to 150 kg of structures per 1 m3 building volume, for residential full-frame building – 250 kg, brick building – 500 kg (Collet-Sabé, 2023; Manakbayeva, 2023; Sheveleva, 2024).

Recently methods of actively implementing various means of transport process automation using modern information technology have taken a prominent place among the many possible directions and ways of improving efficiency. 'Formation and assessment of the quality of design solutions in construction' V. Reusov. Kyiv 1988. It allows for more efficient use of both the transport process as a whole and the individual elements of the process, as well as more effective control of the transport process. We should note that the problem of introducing automated systems into the process of transporting construction cargo is not new and has been sufficiently researched by Varlamov N. V., Mambetova A. V. et al (Giza, 2024; Mambetova et al., 2024; Mascareno & Chavez, 2024).

2. Problem Statement

2.1. Main problems of road transport in the construction industry

Construction transportation has a number of specific characteristics that greatly complicate the problem of ensuring the smooth and efficient operation of the transportation process in the construction industry. We look at some of these characteristics.

1. There are many cargoes and materials transported in the construction industry by road. Almost all the equipment and materials used in construction are brought to the sites by road. Moreover, the efficiency of construction works largely depends on the timely delivery of the required construction materials, machinery, equipment, not earlier and not later than the required time, since the early delivery causes problems associated with the storage and preservation of brought cargo, and the late delivery leads to a violation of the technological cycle of works, up to the forced downtime and violation of construction timeframes.

2. The production process in the construction industry also involves large volumes of additional transport not directly related to the ongoing construction work: moving heavy and bulky construction machinery and construction equipment, removing soil during the preparation of construction pits and construction sites, removing waste during landscaping upon completion of construction work, etc. Therefore, ensuring the coherence of road transport, which delivers and transports construction cargo to construction sites, with the production processes of construction work on the sites is an important condition for high-quality and highly productive work in the construction industry.

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3. In many cases, road transport involves the movement of dangerous, oversized and problematic cargo, which is particularly difficult to move on congested urban highways and roads, where construction vehicles always cause potential traffic congestion. They can cause serious problems in accidents (loads can scatter on the road surface, hindering traffic flow, cause serious damage to other vehicles, injure people due to their heavy weight) and put a heavy load on the roadway, contributing to its rapid failure. Therefore, to minimize losses and costs, the transport of most construction cargo requires the establishment and observance of a specific transport plan and regime: times and routes of transport, weather conditions, traffic conditions in the city during the transportation, etc.

4. A significant part of construction traffic involves the transport of expensive and valuable cargo, which forces an increased level of protection and security of high-value cargo against possible malicious interest in the movement of construction cargo and requires the development and strict observance of special rules and security measures.

3. Research Questions

High competition in the market for construction services forced construction companies to strive for the lowest possible cost of construction work, and above all, at the expense of quality and on-time performance.

4. Purpose of the Study

All the previously discussed features point to the need to use information technology with mathematical models based on system analysis and decision-making to form and implement special technological schemes ensuring high-quality transport operations in all possible situations associated with transport that could have a negative impact on the process of moving goods. Determining the most likely parameter values whose impact will reduce the losses and costs associated with various changes in these factors will solve the problem of maximum preparedness for the process of changing these values. It is possible due to the development of appropriate adaptation mechanisms before starting transport processes.

5. Research Methods

The problem has long attracted a lot of attention. In Soviet times it also received a great deal of attention, as reflected in the large volume of research on the issue by different authors, for example, Velmozhin, S. S. Voytenkov, D. P. Gronin. There is a fairly comprehensive review of the results to improve and raise the efficiency of road transport in the cargo delivery system. However, the most important difference between the conditions of the Soviet period and today is that in Soviet times both the transport and construction industries were owned and controlled by the state and the planned economy. Therefore, the organization of the required transport conditions was based on organizational methods, e.g. the state bodies planned transport routes and schedules for oversize cargo. Further, the construction organization took little or no responsibility for possible damage to the road surface and other road structures occurring during transportation. Finally, a quarter of a century ago, the amount of transport on

the roads and, above all, in cities and megacities was much lower than it is now. Therefore, the transportation planning tasks were set and studied primarily without considering the variety of factors generated by a market economy.

6. Findings

Qualitative solutions for organizing road transport of construction cargo require a mathematical model that considers the variety of technological and market-related parameters that can affect the transport process. The full consideration of all, or at least all major influencing factors is only possible through a systematic approach using information technology. This paper focuses on a systematic analysis of transport planning and implementation. Effective implementation is not possible without the widespread use of computer technology and information technology. Automation in road freight transport has received considerable attention since the 70s. Among the works closest to the topic, we would like to mention the work of A. V. Dmitriev 'System of Transport Service Efficiency Indicators', which has thoroughly and extensively examined this problem.

7. Conclusion

The paper identifies the main areas that significantly complicate the problem of ensuring the smooth and quality running of transportation in the construction industry and points to the need to have, form and implement special technological schemes and algorithms to ensure high performance and quality of transportation work in any possible emergency or other unforeseen situations and all the associated transport factors that may have a negative impact on the delivery process

We have made a general system analysis and developed a functional algorithm describing the process of construction cargo transportation by road, formed a group of factors that affect the process of transportation by road, identified the main functions which serve as the basis for building an automated management system for construction cargo transportation by road, as well as necessary additional algorithms of the said automated system.

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