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EFFICIENCY INCREASE FOR RAILWAY STATIONS AND NON-PUBLIC TRACKS INTERACTION IN OIL-REFINING COMPLEXES

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Abstract

The authors of this article consider specific features of interaction between stations of JSC "Russian Railways" and ways of non-public use of oil refineries. The production volume at well-known enterprises and the production distribution by production structures are given in this paper. The dependence of the output volume of finished products and the interaction with rail transport are determined and analyzed. The existing development method of the unified technological operation process of the railways does not provide a target function combining peculiarities of technology, planning and control elements of the oil-refining railway complex. It is necessary to study and develop recommendations to optimize the interaction between railway stations and ways of non-public use of oil refineries. The identified peculiarities of this interaction, and the carried out experimental calculations, enable to speak about the need for a systematic approach to the problem of the unified technological operation process development and the efficiency increase of such an interaction in modern conditions. Recommendations for improving the operation of the adjoining stations and private railways of oil refineries are based on the proposed digital simulation model and the integrated efficiency indicator for management decisions. The conducted research is based on the analysis of one of the largest refinery complexes in the European part of Russia.

Keywords: Oil-refining industry, station, technology, interaction, criteria, efficiency.

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1. Introduction

The Russian oil-refining industry is one of the largest in the world. In terms of total oil refining, Russia is one of the five world leaders, just after the United States and China in the world rating (Russia in the 21st century, 2013). To some extent, this is due to historical circumstances that almost all serious enterprises in this industry were built in Russia before 1991. At present, the domestic oil industry combines about 30 large refineries with refining volumes of more than 1 million tons of oil and several tens of small ones (Russia in the 21st century, 2013; Expert Online, 2019). Oil refineries and organizations of our state are divided into:

- PCC – petrochemical complexes and companies;
- ORA – oil refining associations;
- ORP – oil-refining plants;
- EOS – enterprises of "organic synthesis".

It is logical that the major share of large enterprises in this sector of the economy is concentrated in the European part of the country. They are concentrated either in places of the greatest consumption of products, or near oil fields. For example, only in the Samara region there are three large refineries. The total amount of processing capacity in Russia is more than 279 million tons per year (Vygon Consulting, 2017). The distribution of enterprises in terms of their output volume is characterized by the diagram presented in Figure 01.

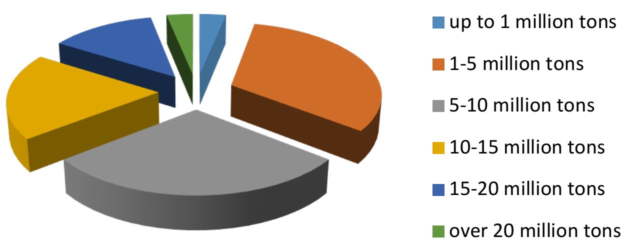

Figure 01. Distribution of enterprises by volume of output
Source: authors based on Kalushin & Soldatkin (2018).

One of the most popular transportation types for products of oil refineries is railway transport. It has more than 40% of all transportation of petroleum products (Shiftman - transport and logistics portal, 2014). When fulfilling tasks of oil cargo transportation, there is a certain systemic interaction between the carrier represented by the adjoining railway station and the consignor – the oil refinery.

2. Problem Statement

The existing development method for a single technological process (STP) of the operation of non-public tracks and the junction station does not provide a target function that combines specific features of technology, planning and management of the oil-loading railway complex elements. It is necessary to

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study and develop recommendations to optimize the operation of the junction station and non-public tracks of petrochemical complexes and companies (PCC).

To solve this problem, the authors studied one of the largest refinery complexes in the European part of Russia, and on the basis of this research, they analyzed the main traffic flows of oil products, identified consequences of the lack of effective interaction of railway transport and oil refineries, as well as key opportunities for developing the cooperation between the refinery and rail transport in Russia.

3. Research Questions

The purpose of a single technological process is to link the operation technology of the junction station and the technology of the non-public tracks (Kalushin & Soldatkin, 2018). The most important elements, in our opinion, of such an interrelated technology work are: organization of loading cars (including routes and groups of cars); execution order of shunting works; supply and appropriate distribution of cars supplied for the fronts of loading and unloading; arrangement order of cars for cargo operations, the implementation and regulation of operations for fixing cars; organization of document flows, characteristics of loading areas, standardization of operation time on the non-public tracks and at the station.

The revealed features allow us to conclude that it would be rational to create a certain “digital” simulation model, which should at least carry out the following functions: input of initial data for modeling the structure and technology of using the station and non-public tracks in a convenient form for users; transformation of the received source data to a standard form (for example, to the terms of a modeling language or other form); calculations based on the model; processing and adjustment of calculation results.

Thus, the following tasks are to be solved:

- define the scope of delivery existence;
- determine the load formation tree;
- determine the delivery route of the formed cargo.

4. Purpose of the Study

The aim of this study is to form:

- mathematical approach to solving this class of tasks;
- requirements to the configuration and volume of source data depending on the task to be solved and imposed restrictions;
- correct the algorithm for solving a problem, represented at the level of the flowchart.

In this case, the role of optimization criteria can relate to simple criteria: the existence of a delivery route; the shortest delivery path; the minimum time of delivery; the minimum delivery cost for a customer; the minimum delivery costs for a contractor, or their combinations as "delivery time is not more than a given one by costs of the customer are not more than specified ones".

In our case, the criterion of the performer’s maximum profit, which is often set in such tasks, is incorrect, since when it is used, the cargo will either stand idle for years at station N, conditionally

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bringing profit in the form of fines for delaying rolling stock, or travel along all the Russian railways. Instead of this criterion, the criterion of the minimum costs of the contractor is considered, free from these shortcomings (Kalushin, 2001).

5. Research Methods

In cases where it is necessary to monitor the operation of each particular technological device that is used, the model should fully display such an object. Devices are displayed using "linked" items. Linked elements are special logic elements that are engaged in time simultaneously with ordinary logic elements. The number of such technological devices, and, consequently, the number of related linked elements in the model is set by the user:

$$\forall u_k \Rightarrow \{e'_i\} \in E', \quad (1)$$
$$E' \subset E,$$

where:

u_k - a technological device;

e'_i - a linked element item corresponding to the device u_k;

E' - a variety of linked elements;

E - a variety of logical elements of the model.

Since the criterion chosen by the user, which needs to be improved, directly or indirectly affects the delays in the model, the functional is the cost indicator of total delays:

$$S = \sum_i \sum_{z_i} \sum_{o_i} c_{ij} \Delta\tau_{ij}(t), \quad (2)$$
$$z_i \in (E \cup Q),$$

where:

S - total cost of delays in the model;

c_{ij} - the cost of a unit delay caused by element z_i in the operation O_j;

$\Delta\tau_{ij}(t)$ - the amount of delay in the operation O_j caused by element z_i at the moment *t*;

E, Q - accordingly, the varieties of logical and bunker elements of the model.

The total cost indicator of delays:

$$S = \sum_j \alpha_j \Delta\tau_j, \quad (3)$$
$$\Delta\tau_j = \sum_i \Delta\tau_j(t),$$

where:

$\Delta\tau_j$ - total delay of the operation O_j;

$\Delta\tau_j(t)$ - delay in the ***j***-th operation at the moment *t*.

The process of optimizing interaction is a series of calculations to achieve a user-defined level with a selected polygon structure and control option. The user changes parameters to reduce delays based on the unit cost:

$$\sum_k \sum_i c_i \Delta\tau_i^k \to \min, \qquad (4)$$

where: *k* - calculation (iteration) number.

In this case, the following costs should be taken into account: operating costs - (E); costs of loading and unloading operations (P); maintenance costs (formation, disbandment, etc.) - (O); costs of communication and document processing - (C); costs of loan interest on loans - (Z); management costs (L), forming the internal costs of the transport interaction:

$$T=E+P+O+C+Z+L \qquad (5)$$

The resulting effects are interdependent and cause each other. The results of management are manifested through the impact on system-wide costs and the amount of reduction in the delivery time. This provides an opportunity to optimize the costs of the carrier while reducing the total time of the final delivery.

The consistent compliance with the conditions of the developed algorithm when working based on the economic optimization criteria (4) allows us to consider the application of the following integral indicator as optimal one for the efficiency of administrative decisions on increase of the interaction efficiency between stations adjacent to oil-refining associations, oil refineries, and the implementation of the full delivery:

$$\eta_0 = \frac{A}{S\{A_1\} + S\{A_2\}}, \qquad (6)$$

where:

A - transportation capabilities, expressed as the total volume of oil cargo transported during the billing period, for example, per year, tons;

$S\{A_1\} = C_H + C_M + C_Q + C_3$ - conditionally useful costs of the carrier, including:

C_H - the amount of salaries for management and maintenance personnel;

C_M - camount of compensation for depreciation of fixed assets;

C_Q - costs associated with cargo preparation, loading, unloading, formation of a train and operational work, as well as measures to prevent losses and damage to transported goods;

C_3 - costs associated with the improvement of management and organization of oil and gas transportation by railway;

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$S\{A_2\} = C_1 + C_2 + C_3 + C_4 + C_X$ - total losses caused by the carrier in the delivery of oil and gas, (in monetary units), including:

C_1 - costs associated with the elimination of "transport defects" of the served clientele;

C_2 - expenses for compensation of losses and deterioration of quality of the transported cargo;

C_3 - the cost of cargo weight in transit;

C_4 - costs of environmental protection from harmful effects of vehicles and transported goods;

C_X- unforeseen expenses (force majeure circumstances and / or other).

6. Findings

The results of the experimental calculation are shown in table 01.

Table 01. The results of the calculation of the criterion η_0

		S{A1}, rubles.										
		500	550	600	650	700	750	800	850	900	950	1 000
S{A2}, rubles.	900	0,714	0,690	0,667	0,645	0,625	0,606	0,588	0,571	0,556	0,541	0,526
	910	0,709	0,685	0,662	0,641	0,621	0,602	0,585	0,568	0,552	0,538	0,524
	920	0,704	0,680	0,658	0,637	0,617	0,599	0,581	0,565	0,549	0,535	0,521
	930	0,699	0,676	0,654	0,633	0,613	0,595	0,578	0,562	0,546	0,532	0,518
	940	0,694	0,671	0,649	0,629	0,610	0,592	0,575	0,559	0,543	0,529	0,515
	950	0,690	0,667	0,645	0,625	0,606	0,588	0,571	0,556	0,541	0,526	0,513
	960	0,685	0,662	0,641	0,621	0,602	0,585	0,568	0,552	0,538	0,524	0,510
	970	0,680	0,658	0,637	0,617	0,599	0,581	0,565	0,549	0,535	0,521	0,508
	980	0,676	0,654	0,633	0,613	0,595	0,578	0,562	0,546	0,532	0,518	0,505
	990	0,671	0,649	0,629	0,610	0,592	0,575	0,559	0,543	0,529	0,515	0,503
	1 000	0,667	0,645	0,625	0,606	0,588	0,571	0,556	0,541	0,526	0,513	0,500
	1 010	0,662	0,641	0,621	0,602	0,585	0,568	0,552	0,538	0,524	0,510	0,498
	1 020	0,658	0,637	0,617	0,599	0,581	0,565	0,549	0,535	0,521	0,508	0,495
	1 030	0,654	0,633	0,613	0,595	0,578	0,562	0,546	0,532	0,518	0,505	0,493
	1 040	0,649	0,629	0,610	0,592	0,575	0,559	0,543	0,529	0,515	0,503	0,490
	1 050	0,645	0,625	0,606	0,588	0,571	0,556	0,541	0,526	0,513	0,500	0,488
	1 060	0,641	0,621	0,602	0,585	0,568	0,552	0,538	0,524	0,510	0,498	0,485
	1 070	0,637	0,617	0,599	0,581	0,565	0,549	0,535	0,521	0,508	0,495	0,483
	1 080	0,633	0,613	0,595	0,578	0,562	0,546	0,532	0,518	0,505	0,493	0,481
	1 090	0,629	0,610	0,592	0,575	0,559	0,543	0,529	0,515	0,503	0,490	0,478
	1 100	0,625	0,606	0,588	0,571	0,556	0,541	0,526	0,513	0,500	0,488	0,476

Source: authors based on Project Plaza (2014).

The calculated values of the criterion are shown in figure 02:

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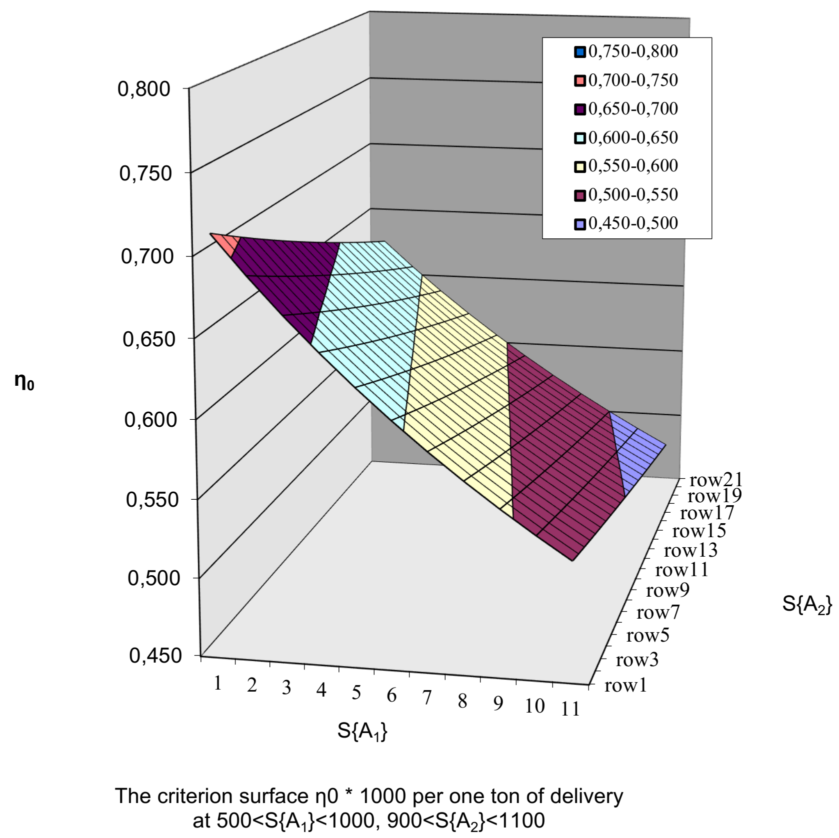

Figure 02. The calculated values

7. Conclusion

According to the data of Shiftman - transport and logistics portal (2014), an oil loading railway complex can have as its component both one or several adjoining stations. The cost of transportation of oil products by railway is formed under the influence of a large number of parameters. The increase in the efficiency of interaction between railway stations adjacent to oil-refining associations and oil refineries is achieved by the selection of technological elements, operations and processes aimed at reducing the total specific (unit) in-transit and non-transport costs (Project Plaza, 2014).

The integral indicator reflects the productivity and is positively correlated with the concept of the intra-transport and non-transport delivery efficiency. The minimum value of the delay, equivalent to the denominator of the expression for an integral indicator of the effectiveness of management decisions, leads to the least costs associated with managing the interaction.

The revealed peculiarities of the interaction of the railway stations adjacent to oil-refining associations and oil refineries, and the performed experimental calculations, allow us to speak about the need for a systematic approach to the problem of both developing the single technological process and increasing the effectiveness of such interaction in modern conditions, as well as continuing more detailed research in this direction.

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