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JUSTIFICATION OF MANAGEMENT SOLUTIONS FOR THE DELIVERY OF DIESEL FUEL TO THE MINES

Vladimir Olizarenko
Magnitogorsk State Technical University named after G.I. Nosov, Magnitogorsk, Chelyabinsk region, Russian Federation

Azamat Allaberdin
Ufa State Petroleum Technical University, Ufa, Republic of Bashkortostan, Russian Federation

Konstantin Vazhdaev
Ufa State Petroleum Technical University, Ufa, Republic of Bashkortostan, Russian Federation

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Abstract

The development of copper-pyrite deposits in the southern Urals is characterized by an increase in depth and, consequently, a complication of mining and geological conditions. As a result, there is a significant increase in the volume of work on the sinking of mine workings, delivery, and rollback of the extracted ore mass. Justification of management decisions on the delivery of diesel fuel to the mine is executed to find the optimal model of the technological scheme of delivery of diesel fuel (diesel fuel) and other fuels and lubricants (further – fuels and lubricants) in the deep horizons of the underground mine (in the sequel - in the mine) with the development of recommendations on designing an optimal model of method of delivery. The latter is achieved by comparing the competitive models of delivery of DT to the mine: fuel tankers (hereinafter-TK) on an inclined ramp, through a pipeline laid in a cased well and in specially equipped mine trolleys and their combinations with a reasonable choice of the optimal model of the technological scheme. According to the results of the research developed methods of rational organization and management of the movement of diesel fuel based on material flows on the principles of logistics concepts, ensuring the formation of counter-flows model logistic schemes. From the above studies, it follows that the delivery of DT to the mine in special trolleys is optimal with minimal time and cost of delivery to deep horizons Gaiskiy underground mine.

Address of the corresponding author:
Vladimir Olizarenko
volizarenko@mail.ru

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The relevance of the delivery of diesel fuel (DF) to the deep horizons of underground mines is explained by an increase in the production of copper-pyrite ore to 6-10 million tons/year (Table 1) at the Gaiskiy and Uchalinskiy GOKs (Table 1) and in the regions of the Russian Federation. At the same time, a decrease in the copper content in the ore to 1.8% is clearly expressed, which is accompanied by an increase in the cost of extracting 1 ton of ore in the cost of which 35% falls on diesel fuel.

Table 1. Production volumes (a) and wholesale prices (b) for diesel fuel, fuels, and lubricants

a)

Mining enterprise	Production volumes, million tons/year					
	2010	2012	2014	2016	2018	2020
Gaiskiy GOK	5.0	5.25	6.0	7.0	7.9	9.0
Uchalinskiy GOK	4.2	4.8	5.0	5.25	5.5	

b)

№	Name of the material, lubricant	Unit	Unit price with VAT
1	Diesel fuel, winter fuel	RUB/ton	37,000
2	Diesel fuel, summer	RUB/ton	34,000
3	Oil: the average price	RUB/ton	118,376
	Motor	RUB/ton	130,000
	Industrial	RUB/ton	55,000
	Hydraulic	RUB/ton	151,505
	Compressive	RUB/ton	60,375
	Lineshaft	RUB/ton	195,000
4	Plastic lubricant	RUB/ton	70,000

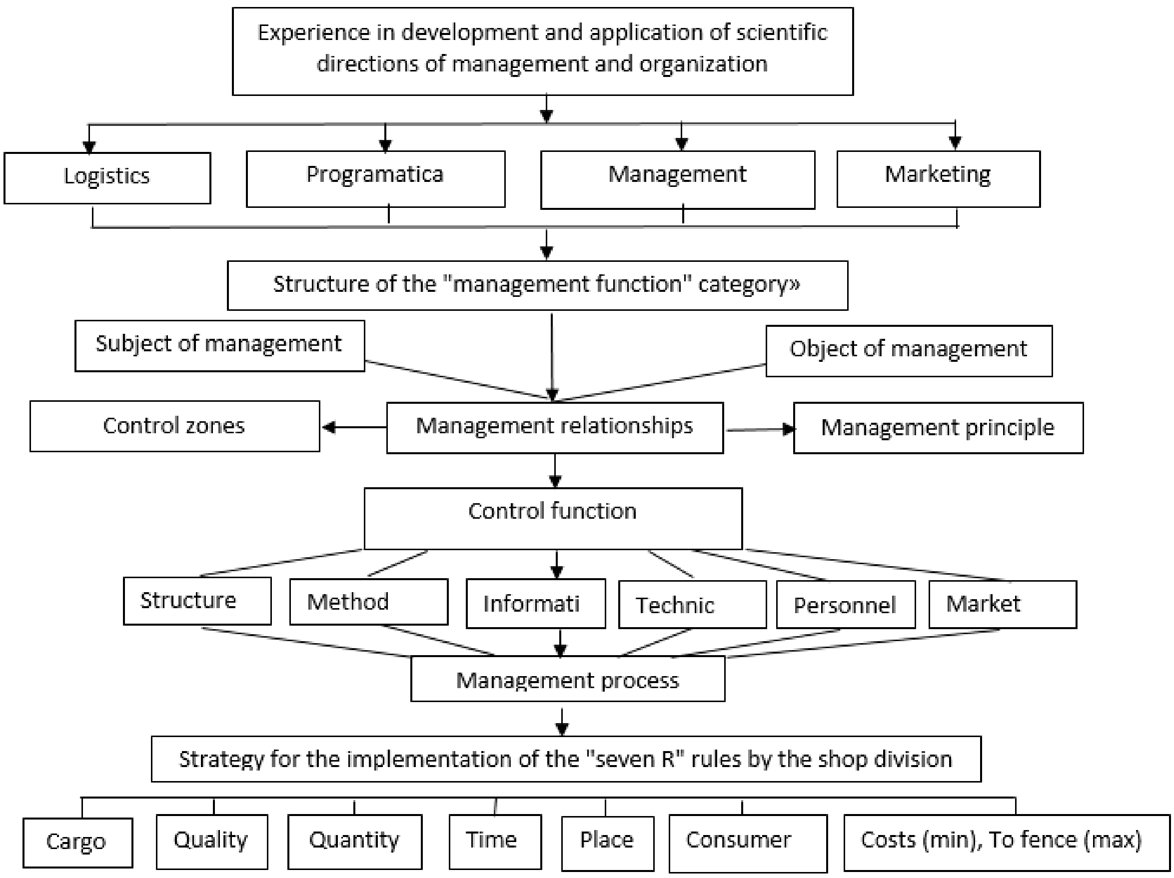


Figure 1. Place of the category "management functions" in the management process

At present, the experience of application and further development of modern scientific directions of management and organization of the development of the mining-technical system "mine-quarry-factory" as part of a mining and processing plant (GOK) is possible based on using the principles of the logistics concept, rochematics, management and marketing (n.d. 2017) (Gavrishev, Rakhmangulov, & Gryaznov, 2002) (Laptev, 2018) (Olizarenko, Krasavin, Abdrakhmanov, & Goltsov, 2013) (Fig. 1).

At the same time, the place of the category of "management functions" in the management process with the allocation of the category of "management functions" in the management structure (Fig. 1) using the principle of decentralization of the main task of profitable mining of ore mass and the allocation of one auxiliary task for the delivery of diesel fuel to the deep horizons of the mine with the implementation of the strategy and requirements of the modern rules of the "seven R" (Gavrishev, Rakhmangulov, & Gryaznov, 2002) underground mine.

A retrospective of the correctness of making strategic management decisions at all periods of the reconstruction of the Gaysky underground mine and the GOK based on the logistic concept and management principles for the development of three Gaysky open-pit mines No. ÷ 1310 m for the periods of 4 reconstructions (from 1960 to the present) of the Gaysky GOK and the underground mine, is confirmed by the positive results of the development of the Gaysky deposit and the empirical dependences obtained on the graphs (Fig. 3) from the beginning of the operation to the present time.

Achievement of such significant indicators of ore extraction volumes up to 6-10 million tons per year at underground mines is ensured both by further improvement of the applied ore mining technology and by solving the separate task of delivering diesel fuel to the deep horizons of mines.

A retrospective of the correctness of making management decisions on the development of open-pit and underground mining operations (OGR and PGR) and the ongoing reconstructions at PJSC "Gaysky GOK" and the underground mine of the same name is shown both for the development of open-pit mine (Fig. 2), and on entering deep horizons. The positive management decisions of which are confirmed by the established dependencies of the volumes of ore mined for the periods of ongoing reconstruction (Fig. 3).

Figure: 2. A retrospective of managerial decision-making on the development of Gaysky

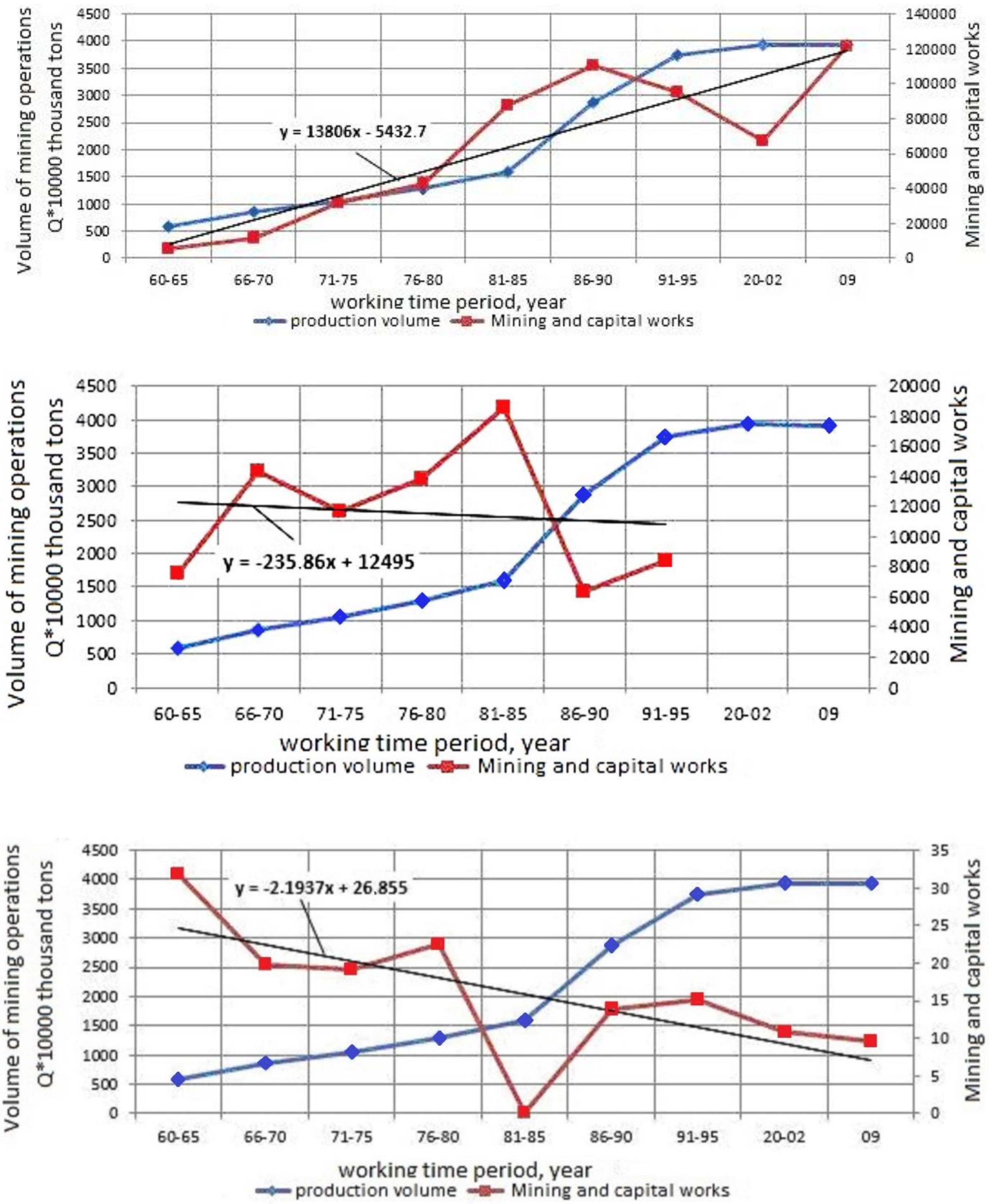


Figure: 3 Dependences of the volumes of mined ore for the periods of ongoing reconstruction (b)

The basis for the implementation and achievement of a high concentration of mining operations with an annual production capacity of 6 ÷ 10 million tons, is focused on the management decisions of the management of the Gaysky GOK, design organizations "UMMC-Mekhanobr" and other studies, where the idea of building essentially a "new mine in an existing mine" (PJSC "Gaysky GOK"), which allows planning the operation of the underground mine and Gaysky GOK for decades in the near future.

At the same time, the search for management decisions on the scientific substantiation of the optimal model of the technological scheme for delivering diesel fuel to the mine was carried out according to the experience of delivering diesel fuel to the mine:

- refuelers on an inclined ramp at the Gaysky mine.
- through a pipeline in a borehole and trolleys at analogous mines Oktyabrsky (a) Norilsk MMC, Nikolaevsky (b) LLP Kazmys, Uzelginsky (c) PJSC Uchalinsky GOK (Fig. 4).

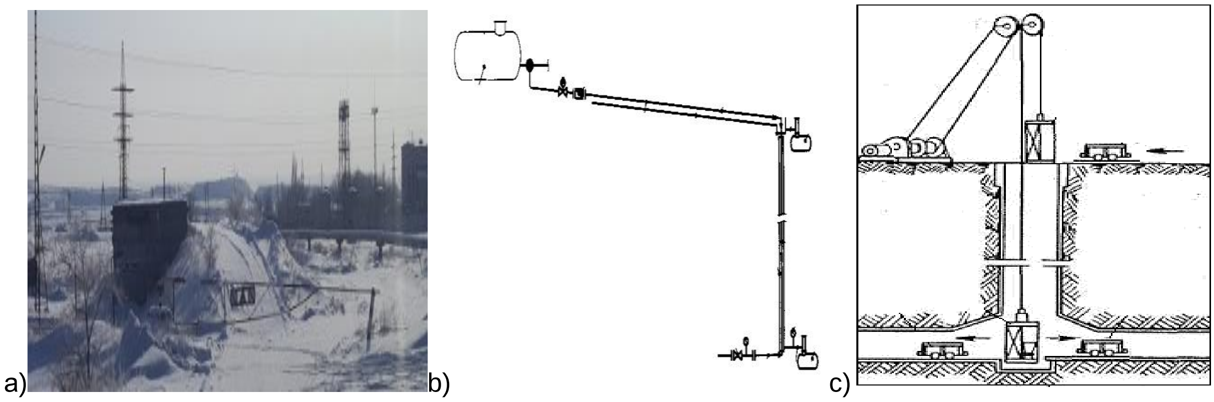


Figure 4. General types of surface equipment (a) downhole delivery of diesel fuel to the mine (b) and delivery of diesel fuel in special trolleys in the cage (c) along the auxiliary cage shaft

The correctness of managerial decision-making by the managers of underground mines based on the trends carried out by foreign and domestic companies made it possible to form a fleet of self-propelled vehicles with internal combustion engines (Table 2).

Table 2. Distribution of self-propelled vehicles with internal combustion engines by purpose

№	Name of self-propelled vehicles cars	Gaisky underground mine		Uchalinsky underground mine	
		number of pieces	%	number of pieces	%
1	Drilling machine	44	19.73	8	12.0
2	Loading and delivery machine	45	20.18	11	15.1
3	Autodumpers	42	18.83	23	32.3
4	Auxiliary machine	92	41.23	29	40.6
	Subtotal:	223	100.00	71	100.0

Based on the data of the studies carried out, a methodology for the rational organization and control of the movement of diesel fuel was developed based on the movement of material flows on the principles of a logistics concept, which ensures the formation of oncoming traffic flows according to the model of a logistics scheme (Fig. 5).

A logistic model for modeling the technological flow of diesel fuel delivery to the mine on the horizons of the operation of self-propelled vehicles with internal combustion engines makes it possible to track and determine the costs of transporting both ore mass and diesel fuel by self-propelled vehicles with internal combustion engines in terms of the time of their delivery to the consumer at a given level of quality and transport services.

The final criterion for choosing the optimal method for delivering diesel fuel to the mine is determined by the adopted management decisions based on the principles of logistics and rochematics, marketing and management based on the final data of economic and mathematical modeling of cost indicators concerning the conditions of the Gaysky mine, considering the factors affecting environmental, social, and sanitary norms and rules.

Substantiated transport-complex modules and logistic models of diesel fuel flows made it possible to develop a technical and economic model for calculating the parameters of diesel fuel delivery to the mine:

$$C\sum_{i=1}^{N}(t_{dv.oc.i}{}_{sp.i}\; min_{min}) \quad (1)$$

where is the time of delivery (movement) along the route of a given (i-th) volume (Qdt, t, m3) of diesel fuel (DF) in a vehicle (refueller, trolley on a rail track) or a gravity flow through a fuel pipeline laid in a borehole with the determination of the diesel fuel movement time (tdv i, min.) along the length of the transportation path (ltr, m) along:

- the main 3 competitive models of technological schemes:

$$t_{dv.TZ.i} = f(n_{TZ.i}\cdot Q_{TZ.i}, L_{tr}, L_{nc}, \upsilon_{TZ.i}, q_{m.nas.i}) \rightarrow min \quad (2)$$

$$t_{dv.w.i} = f(L_{tr}, \upsilon_{TZ.i}, D_{w.i}\cdot Q_{w.i}, H_{gor.i}, L_{gor.i}, \upsilon_{w.i}, q_{m.nas.i}) \rightarrow min \quad (3)$$

$$t_{dv.vag.i} = f(n_{vag.i}\cdot Q_{vag.i}, H_{ш.вер.i}, L_{gor.i}, \upsilon_{vag.i}, q_{m.nas.i}) \rightarrow min \quad (4)$$

$$t_{dv.ak.(TZ+vag)} = f[(n_{TZ.i}\cdot Q_{TZ.i}, \upsilon_{TZ.i}, q_{m.nas.i}) + + (L_{tr}, n_{vag.i}\cdot Q_{vag.i}, H_{gor.i}, L_{gor.i}, \upsilon_{vag.i}, q_{m.nas.i})] \rightarrow min \quad (5)$$

- and 2 alternative combined models of technological schemes:

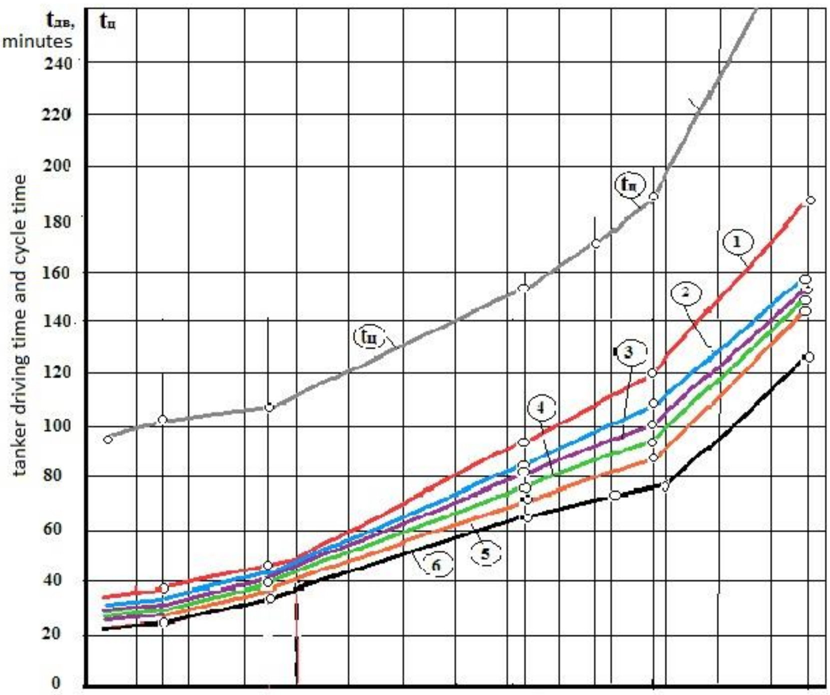
$$t_{dv.ak.(T3+w)} = f[(n_{TZ.i}\cdot Q_{TZ.i}, L_{tr}, L_{nc}, \upsilon_{TZ.i}, q_{m.nas.i}) + + (L_{tr}, n_{vag.i}\cdot Q_{vag.i}, H_{gor.i}, L_{tr.i}, \upsilon_{vag.i}, q_{m.nas.i})] \rightarrow min \quad (6)$$

$$C_{sp.i} = t_{dv.i}\cdot q_{sp.i} \quad (7)$$

where qsp.i - unit cost costs for diesel fuel delivery to the mine according to competitive basic (f. 2-4) and alternative combined (f. 6, 7) models of technological delivery schemes, rubles/min.

Approbation of the developed mathematical and technical and economic model of technological schemes and methods for calculating the parameters of diesel fuel delivery to the mine by i-types of fuel tankers, borehole delivery and delivery in special trolleys are described in detail and given in (n.d., 2017) and (Leptaev, 2018).

A consolidated model of technological delivery schemes combined with the results of calculating parameters in tabular form is shown in Fig. 5.



(a)

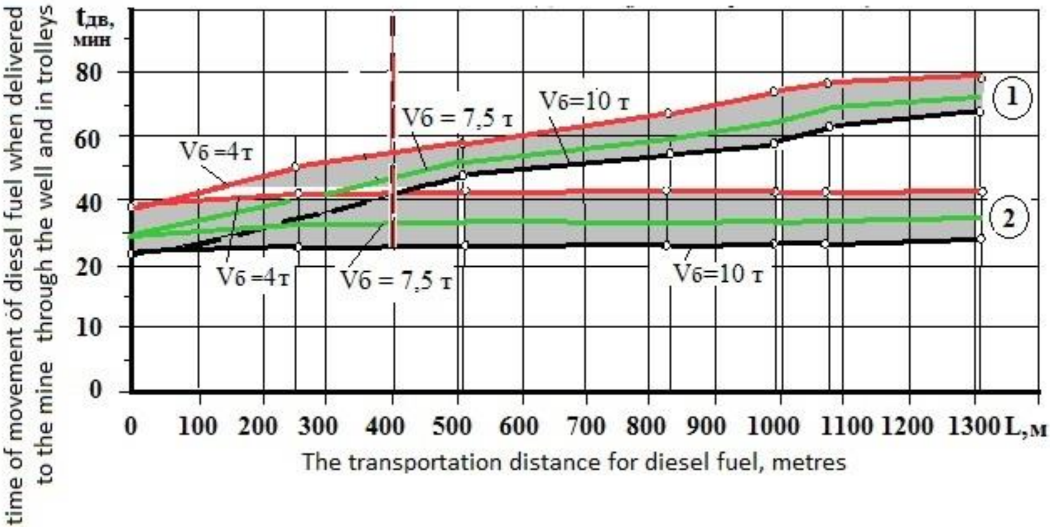


Figure 5. A generalized graph of the dependences of the time of movement (tdv, min) of diesel fuel into the mine to the j-th horizon by delivery methods

On figure 5 there are presented dependences of the time of movement (tdv, min) of diesel fuel into the mine to the j-th horizon by delivery methods:

a. - by tankers No. 1-6 with a tank capacity, respectively, V_b = 4, 5, 7, 7.5, 8.5, & 10 tons.
b. 1 - through a pipeline installed in a borehole.
c. 2 - in a special trolley in the cage of the auxiliary cargo and human cage lift.
d. 3 - in a combined way: in tankers up to the horizon of 510 m and below the horizon of 510 m - through a pipeline installed in a well.

According to the calculation of the parameters for the delivery of diesel fuel to the mine by the main and alternative delivery methods (Fig. 5), calculations were made and graphs of the cost costs (Fig. 6) for the delivery of diesel fuel to the mine using competing and alternative options were made.

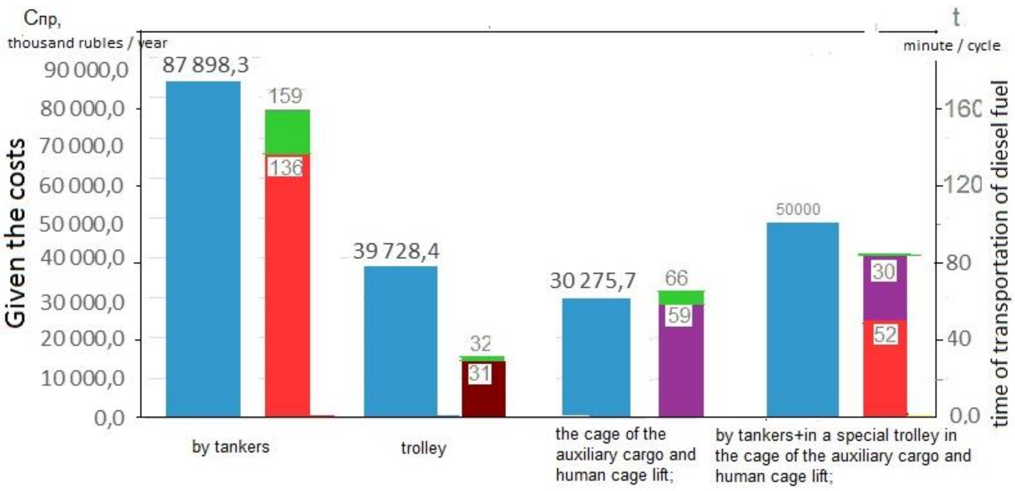


Figure 6. Graphs of the reduced costs for diesel fuel delivery to the mine by competing and alternative options

From the above data, it follows that the delivery of diesel fuel to the mine in special trolleys is optimal with minimal time and cost of delivery to deep horizons (horizons 510 ÷ 1310 m) of the Gaysky underground mine.

The performed studies have established:

1. The existing method of delivering diesel fuel to a mine of TK of the i-th types is among the competitive methods of delivering diesel fuel to the mine in terms of the time spent on the

transportation distance at a depth of mining, not more than 400 m.

2. At depths of up to 400 m, in terms of the delivery time of diesel fuel to the mine, the option of borehole delivery is competitive, in the time spent, which does not take into account the difficulties of maintaining the system of wells in working order, the impact of mining on the borehole, possible losses of diesel fuel from leaks inside the borehole pipeline connections and the complexity of their elimination.
3. At all depths of the mine, the most preferable option for delivering diesel fuel to the mine is delivery in special trolleys, but the calculated operating time in the cycle of delivering diesel fuel to the mine does not take into account the actual load of the cage lift and the possibility of its use for delivering diesel fuel in trolleys to the mine during the shift, days.

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