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# ANALYSIS OF ORE DELIVERY COSTS DEPENDING ON THE PRODUCTIVITY OF VARIOUS TYPES OF LOAD-HAUL-DUMP MACHINES

The effectiveness of extraction operations and the comprehensive quantitative and qualitative recovery of ore reserves are critical issues in the development of high-grade iron ore through sublevel caving systems in Kryvbas mines [1]. A primary technological process in this system is ore release through horizontal bottom drifts of the receiving levels [2]. Ore transportation is a crucial component of the extraction process, determining the efficiency of ore release and overall mining productivity [3]. The selection of transportation equipment significantly impacts the organization of work and the productivity of the entire block [4]. In modern underground ore deposit extraction systems, ore release and transportation are among the most labor-intensive and inefficient processes [5]. The release of fragmented ore from the extraction area is typically carried out from under caved surrounding rock or through a network of specialized drifts uniformly distributed beneath the extraction face. The ore moves through the extraction area and release drifts under the influence of gravity.

However, only about 50% of pure ore is recovered due to horizontal limitations in the release figure dimensions. To reduce ore dilution, sequential releases from adjacent drifts are made in equal or varied doses, as per established release plans. However, current release methods cannot fulfill these plans due to frequent blockages in the release drift necks and the avalanching flow of ore when these blockages are cleared. Consequently, the release process is prolonged and marked by high ore losses and dilution, reaching up to 25% and 18%, respectively.

Based on the calculations performed using the economic-mathematical model, graphical dependencies were constructed to illustrate the specific costs of ore delivery relative to the productivity of various types of Load-Haul-Dump (LHD) machines used in secondary ore transport. These relationships are presented in Fig. 1. The results provide insights into the cost-effectiveness of different LHD machine types under varying productivity conditions, allowing for an optimized approach to secondary ore transportation.

Fig. 1 shows that the lowest specific ore delivery costs are achieved when using a combined scraper-self-propelled transport method, utilizing multi-bucket scraper winches of the 55LS-2SMA type for primary delivery, and the self-propelled LHD ST7 type for secondary delivery. This scheme has the lowest cost indicators when the average transport distance is within the range of 120–270 m. Under these conditions, the productivity of the system is between 720–1110 tons per shift, which is 1.4–3.3 times higher than when using only scraper winches for ore delivery.

A significant reduction in specific ore delivery costs is achieved by increasing the average transport distance from 120 m to 270 m, as seen in Fig. 3. This reduction is due to a notable decrease in specific capital expenditure for constructing the primary ore pass, dropping from $1.24 per ton to $0.21 per ton. However, there is a corresponding decline in the productivity of the self-propelled LHDs used in secondary ore delivery, with performance decreases as follows: EST2D from 460 tons per shift to 264 tons per shift, ST2D from 600 tons per shift to 375 tons per shift, ST3.5 from 950 tons per shift to 620 tons per shift, ST7 from 1110 tons per shift to 730 tons per shift, ST1030 from 1610 tons per shift to 1050 tons per shift, LH409E from 1500 tons per shift to 890 tons per shift, and TORO400D from 1520 tons per shift to 990 tons per shift.

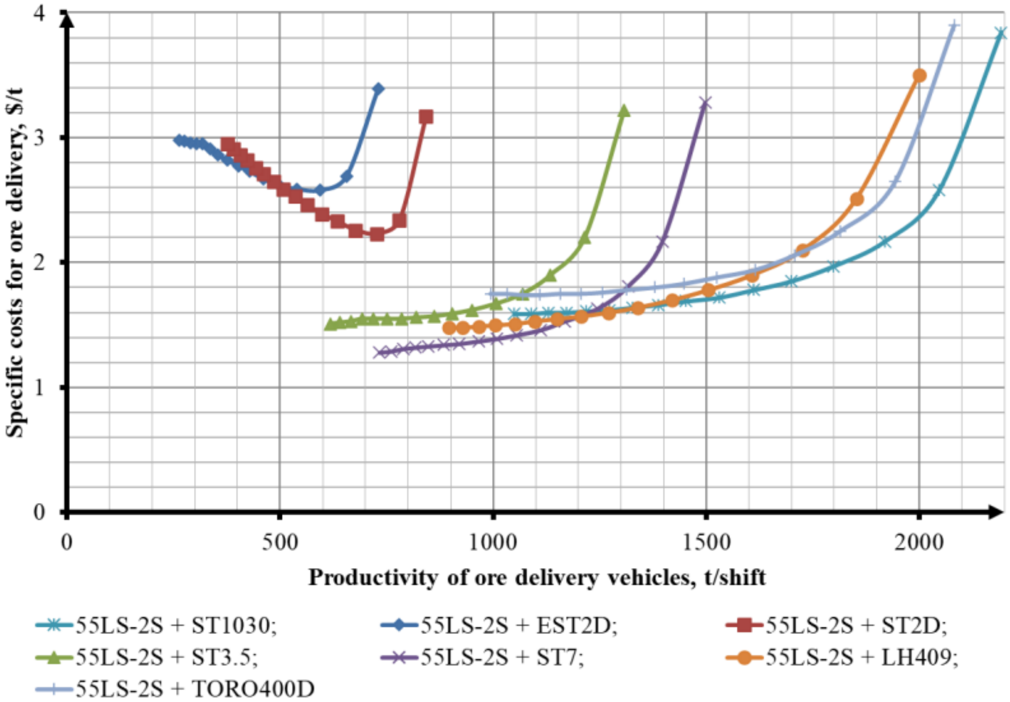


Fig. 1. The dependence of specific ore delivery costs on the productivity of various LHD machine types [own study]

By approximating the maximum values, an empirical dependency was obtained to describe how specific capital costs for constructing the primary ore pass change with respect to the balance of ore reserves. This dependency highlights the relationship between the ore reserves allocated to a single ore pass and the associated capital investment required for its construction. As the balance of ore reserves increases, the model demonstrates how specific costs can be optimized, providing a clear framework for cost management. The empirical model also allows for adjustments based on varying reserve balances, making it adaptable to different mining conditions. Overall, understanding this dependency is crucial for making informed decisions on resource allocation and reducing construction expenses in ore pass development. The specific costs for constructing the primary ore pass, depending on the balance of ore reserves transported by one ore pass to the receiving level, can be determined by the formula:

$$P_{vytr.} = 200.27 B_{zap.}^{1.422}, \text{ \$/thousands tons with } R^2 = 0.9848,$$

where: $B_{zap.}$ – ore reserves per primary ore pass, thousands of tons; $R^2$ – approximation accuracy

The study concludes that the use of self-propelled equipment for ore delivery in sublevel caving systems, as applied in the Kryvbas mines, is both feasible and economically justified when employing a combined scraper-self-propelled transport approach. For secondary ore delivery, specific selfpropelled Load-Haul-Dump (LHD) machines, such as the EST2D, ST2D, ST3.5, ST7, ST1030, LH409E, and TORO400D, were found to be particularly suitable and cost-effective.

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