ANALYSIS OF THE ECONOMIC EFFICIENCY OF IMPLEMENTING ELECTRONIC CONVEYOR SCALES AT COPPER PROCESSING PLANT 2.

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ABSTRACT This article presents a technical and economic analysis of the feasibility of replacing mechanical conveyor scales with electronic ones at mills No. 6, 8, 10, and 12 of the Copper processing plant No. 2 in Uzbekistan. The relevance of the study stems from the increasing requirements for the accuracy of metrological accounting in the mining and beneficiation industries, as well as the need to optimize the consumption of process reagents and energy resources in the context of resource-intensive production. A comparative analysis of the metrological characteristics of mechanical and electronic conveyor scales was conducted; the absolute and relative errors in accounting for processed ore were calculated for each type of equipment; and a quantitative assessment of the annual economic benefit from the implementation of more accurate measuring instruments was provided. Issues related to standardizing the consumption of flotation reagents and electricity depending on the accuracy of weight control are examined. It has been established that switching to electronic scales reduces the relative error in accounting for processed ore from 2% to 1%, thereby reducing the absolute error by approximately 19,700 tons per year, which accounts for about 50% of the error of mechanical scales. The payback period for capital investments in new equipment does not exceed 7 months, which indicates the high investment attractiveness of the proposed technical solution. The results obtained can be used when planning technical modernization programs for similar processing plants.

KEYWORDS conveyor scales, electronic scales, measurement error, ore beneficiation, economic benefit, CPP-2, equipment modernization

Introduction

The mining and metallurgical industry is one of the key sectors of Uzbekistan's economy, accounting for a significant share of the country's industrial output and export potential (Kirsanov, 2022). One of the largest facilities in the industry is the Almalyk Mining and Metallurgical Complex, which draws its raw materials from the Kalmakyr deposit, one of the largest copper-porphyry deposits in Central Asia (Cheng, 2018; Islamov, 2021). The mined ore is processed at copper concentrators, where the efficiency of production processes depends directly on the accuracy of material flow control throughout the entire value chain, beginning with ore extraction in the open pit. This includes effective drilling and blasting operations, loading and haulage of the mined material, primary and secondary crushing, ore stockpiling and blending, grinding and classification processes, as well as subsequent beneficiation stages (Toshov J. T., 2025; Alikulov Sh, 2025; Toshov J.B., 2024). Accurate monitoring and accounting of material flows at each of these stages are essential for maintaining process stability, optimizing equipment utilization, reducing losses, and ensuring the efficient recovery of valuable minerals.

Copper Processing Plant №2 (CPP-2), located in the Tashkent Region of the Republic of Uzbekistan, processes copper ore from the Kalmakyr deposit Figure 1. In a high-throughput mining operation, accurate measurement of the mass of processed raw materials is of particular importance, as these measurements are used to calculate the consumption of flotation reagents, electricity, water, and other production resources. Even minor deviations in the readings of weighing equipment can lead to significant economic losses due to the accumulation of errors when processing millions of tons of ore annually.

Belt scales are among the most critical tools for process control in mineral processing plants. Their readings serve as the basis for real-time management of grinding and flotation processes, as well as for planning the plant's production targets. At the same time, mechanical conveyor scales continue to be used in a number of process areas, although their metrological characteristics are inferior to those of modern electronic measurement systems (Deka, 2024; Toshov J. S., 2026; Rozikulov A. D., 2026). The higher error margin of mechanical scales reduces the accuracy of ore processing accounting and negatively affects the efficiency of reagent and energy consumption management.

Figure. 1. Kalmakyr deposit in Uzbekistan.

The accuracy of weight accounting for processed ore is one of the key factors in the effective management of the production process at ore processing plants (Hodouin, 2011; Rozikulov A. D., 2025). Belt scales are primary measuring instruments whose data are used to calculate the consumption of flotation reagents, water, electricity, and other resources allocated per ton of processed ore. Systematic errors in determining ore mass accumulate over the course of the production cycle and lead to significant discrepancies between planned and actual resource consumption figures. At a plant processing millions of tons of ore per year, even a slight reduction in measurement error yields a tangible economic benefit. Despite this, a number of mining and processing enterprises still operate mechanical belt scales with a relative error of up to 2%, whereas modern electronic equivalents provide an error of no more than 1% at comparable operating costs (Pryor, 2012; Mular, 2002).

The issue of modernizing weighing equipment is relevant from both a technical and an economic perspective. On the one hand, improving the accuracy of primary measurement lays the groundwork for more effective control of reagent usage and a reduction in specific energy consumption. On the other hand, any technical solution requires an economic justification that includes an assessment of investment costs and the payback period. The objective of this study is to provide a comprehensive justification of the economic feasibility of replacing mechanical belt scales with electronic ones at mills No. 6, 8, 10, and 12 of the processing plant 2. To achieve this objective, the following tasks were addressed: a comparative analysis of the metrological characteristics of two types of weighing equipment in accordance with the requirements of GOST R 8.683 (Shikhov, 2025; Dovydenko, 2021; Tumilovich, 2024), Quantitative calculation of the annual absolute error in the accounting of processed ore for each type of scale; assessment of the error's impact on the accuracy of reagent and energy consumption standards; determination of the annual economic benefit from the implementation of new equipment; calculation of the payback period for capital investments using the simple payback method.

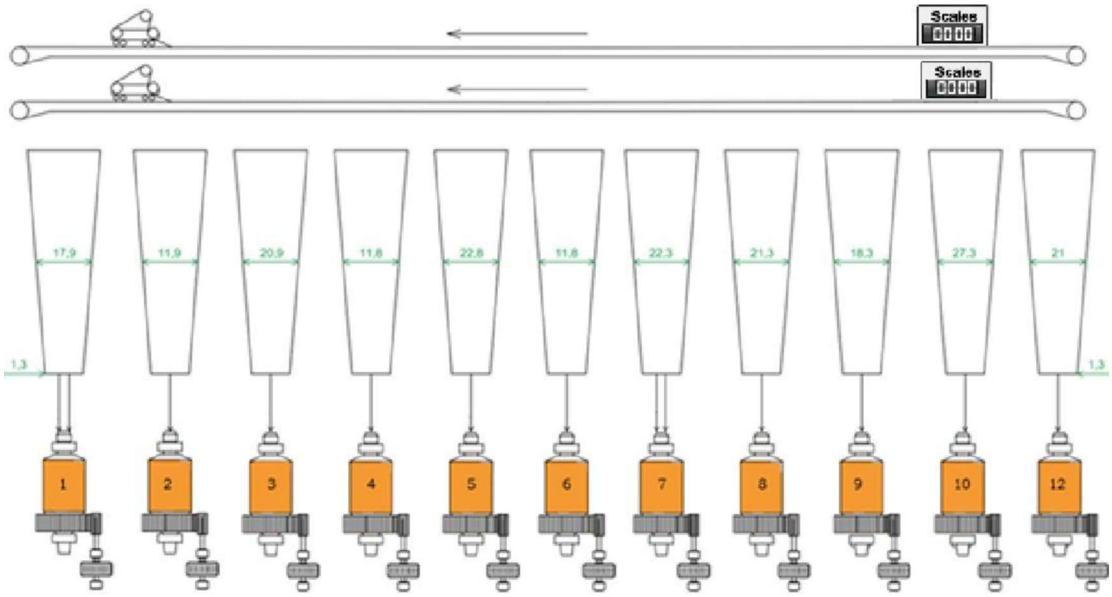

Figure 2. Schematic diagram of the grinding section in the CPP-2.

Subject of the study and calculation methods

The subject of this study is four conveyor mills at the CPP-2, № 6, 8, 10, and 12—equipped with mechanical scales that are due for replacement. The mills' capacities are as follows: Nos. 6, 8, and 10 — 45 tons per hour each; No. 12 — 90 tons per hour. The average capacity for the group is 56.2 t/h.

The average annual ore processing volume at these mills was calculated using the following formula:

$$Q = q \cdot n \cdot t \cdot T = 56{,}2 \cdot 4 \cdot 24 \cdot 365 = 1\ 969\ 248 \text{ t/year},$$

where q — average output per mill (tons per hour); n — number of mills; t — number of hours in a day; T — number of days in a year.

The economic benefit of reducing measurement error was calculated based on the difference between the absolute errors of mechanical and electronic scales, adjusted for the annual processing volume, followed by a cost assessment of the savings in reagents and electricity. The payback period was determined as the ratio of the total cost of purchasing new equipment to the annual economic benefit.

Results and Discussion

Comparative Analysis of Weighing Equipment Accuracy The error of mechanical conveyor scales in determining the mass of processed ore is 2%, whereas the error of electronic scales is 1%. The comparative performance metrics for the two types of equipment, assuming the same annual processing volume, are presented in Table 1.

Table 1.
Comparative Analysis of the Accuracy of Weighing Equipment.

Indicator	Mechanical scales	Digital scales
Measurement error	2,0 %	1,0 %
Annual processing capacity, tons	1 969 248	1 969 248
Absolute error per year, t	39 385	19 692
Difference in errors, t/year	—	19 693

As shown in Table 1, the use of electronic scales reduces the absolute annual error from 39,385 to 19,692 tons, or by 19,693 tons per year. This difference directly affects the accuracy of planning for the consumption of reagents and energy resources.

Economic impact

The consumption of flotation reagents, water, electricity, and other resources is calculated for ore processing. Any error in recording the processed volume results in a corresponding error in the calculation of these consumption figures. Switching to electronic scales with higher measurement accuracy leads to cost savings through more precise resource allocation.

The total annual economic benefit of replacing the scales amounts to *$104,546*, as confirmed by a detailed calculation of reagent consumption and energy costs (Table 1: Economic Benefit Calculation, attached to this paper).

Investment Evaluation and Payback Period

The cost of purchasing and installing four electronic conveyor scales is approximately $58,000. Payback period:

$$T_{payback\ period} = 58.000\ \$ \ /\ 104.546\ \$ \approx 0,56\ years\ (6–7\ months).$$

The resulting payback period is significantly less than one year, which, according to generally accepted criteria for evaluating investment projects, indicates the high economic efficiency of the proposed technical solution.

Conclusions

Based on the study conducted, the following conclusions have been drawn:

– Replacing the mechanical conveyor scales with electronic ones at mills No. 6, 8, 10, and 12 of the CPP-2 plant is technically and economically justified.

– The switch to electronic scales reduces the margin of error in tracking processed ore from 2% to 1%, which amounts to 19,693 tons per year.

– Improved measurement accuracy allows for the optimization of reagent consumption and energy costs, resulting in an annual cost savings of *$104,546*.

– With capital costs of approximately *$58,000*, the project's payback period is 0.56 years (approximately 6–7 months).

– The project is recommended for implementation as scheduled as part of the technical modernization program for the CPP-2 factory's equipment.

АНАЛИЗ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ ВНЕДРЕНИЯ ЭЛЕКТРОННЫХ КОНВЕЙЕРНЫХ ВЕСОВ НА МЕДНОМ ОБОГАТИТЕЛЬНОМ ЗАВОДЕ - 2.

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АННОТАЦИЯ В данной статье представлен технико-экономический анализ целесообразности замены механических конвейерных весов на электронные на комбинатах № 6, 8, 10 и 12 второго медеперерабатывающего завода в Узбекистане. Актуальность исследования обусловлена растущими требованиями к точности метрологического учета в горно-обогатительной промышленности, а также необходимостью оптимизации расхода технологических реагентов и энергоресурсов в условиях ресурсоемкого производства. Проведен сравнительный анализ метрологических характеристик механических и электронных конвейерных весов; рассчитаны абсолютные и относительные погрешности учета переработанной руды для каждого типа оборудования; дана количественная оценка годовой экономической выгоды от внедрения более точных измерительных приборов. Рассмотрены вопросы, связанные со стандартизацией расхода флотационных реагентов и электроэнергии в зависимости от точности контроля веса. Установлено, что переход на электронные весы снижает относительную погрешность учета переработанной руды с 2 % до 1 %, что позволяет сократить абсолютную погрешность примерно на 19 700 тонн в год, что составляет около 50 % погрешности механических весов. Срок окупаемости капиталовложений в новое оборудование не превышает 7 месяцев, что свидетельствует о высокой инвестиционной привлекательности предлагаемого технического решения. Полученные результаты могут быть использованы при планировании программ технической модернизации аналогичных обогатительных фабрик.

КЛЮЧЕВЫЕ СЛОВА конвейерные весы, электронные весы, погрешность измерения, обогащение руды, экономическая выгода, МОФ-2, модернизация оборудования.

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MECHANICAL AND TRIBOLOGICAL PROPERTIES OF DRILLING TOOL BITS: A REVIEW

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ABSTRACT Drill bits employed in oil and natural gas exploration operate under extremely harsh tribological environments characterized by high contact stresses, abrasive rock formations, elevated temperatures, corrosive drilling fluids, and cyclic impact loading. The performance, reliability, and service life of these drilling tools are largely governed by their mechanical and tribological characteristics. Therefore, the development and selection of drill bit materials require an optimal combination of high wear resistance, superior hardness, low coefficient of friction, excellent fracture toughness, thermal stability, and resistance to erosion and corrosion. Wear mechanisms such as abrasive wear, adhesive wear, erosive wear, thermal degradation, and fatigue-induced failure significantly influence drilling efficiency and operational costs. Advanced materials, including tungsten carbide composites, polycrystalline diamond compact cutters, thermally stable polycrystalline diamond, cubic boron nitride, and other superhard materials, have been extensively utilized to enhance performance under severe drilling conditions. This review summarizes the essential mechanical and tribological properties required for drill bits used in oil and gas exploration and discusses their influence on drilling efficiency, bit longevity, and failure prevention. Understanding these properties is important for the design and development of next-generation drilling tools capable of operating efficiently in increasingly demanding geological environments.

KEYWORDS drill bits; mechanical properties; tribological properties; friction; wear; corrosion resistance; PDC cutters; tungsten carbide.

1. Introduction

In oil and natural gas exploration, the reliability, availability and maintainability (RAM) of drilling equipment play an important role in increasing production and operational efficiency [1-4]. To achieve high RAM, it is necessary to reduce failures occurring during drilling and exploration. Common failures in drilling operations are closely associated