World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Analysis of the impact of the WENCO system on the productivity and operational efficiency of the production equipment of the Guinea Bauxite Company (CBG)

Ibrahima Kalil KOUROUMA [1,*], Alain GBILIMOU [1] and Mamadouba CONTE [2]

[1] *Lecturer and researcher at the Higher Institute of Mines and Geology of Boké.*
[2] *Lecturer and researcher at the Valery Juscar Destin Institute of Agronomic Sciences of Faranah.*

World Journal of Advanced Research and Reviews, 2026, 29(01), 512-536

Publication history: Received on 22 November 2025; revised on 06 January 2026; accepted on 09 January 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.29.1.4315

Abstract

This article examines the impact of the WENCO system on the productivity and operational efficiency of the production equipment of the Guinea Bauxite Company (CBG). The WENCO system, used as an integrated fleet management solution, provides real-time monitoring of loading, transport, and unloading activities through various hardware and software components such as MDTs, GPS antennas, Fleet Control, Bench Manager, Stockpile Manager, and Wenco DB.

Analysis of 2022 operational data reveals a production shortfall of nearly 198,000 tons, attributed to underutilization of equipment, low availability rates, inefficient management of operating cycles, and inadequate system configuration. Significant discrepancies between the nominal and actual capacities of excavators and dump trucks highlight inefficiencies related to unplanned downtime, under-filling of skips, mechanical breakdowns, and an imbalance between loading and hauling units. Actual operating time, often less than 70%, confirms these shortcomings.

Pareto analysis identifies three main sources of productivity losses: mechanical breakdowns, waiting times caused by excavator/truck imbalance, and inappropriate reassignments resulting from insufficient system parameterization.

Despite these limitations, the study confirms that WENCO represents a strategic tool for mining optimization, contributing to improved operational control, better inventory management, and cost reduction. However, the system's effectiveness depends on the quality of maintenance, technical configuration, staff training, and data reliability. The article concludes that WENCO's performance at CBG depends on the synergy between technology, organization, and human management, requiring a continuous approach of innovation and improvement.

Keywords: WENCO system; Mining fleet management; Equipment productivity; Operational efficiency; Performance analysis

1. Introduction

In an international environment where competition is fierce in the extractive sector, mastering productivity and operational efficiency represents a pivotal strategic challenge in preventing productivity declines, a prerequisite for continuous production, achieving profitability targets, and strengthening competitiveness in the face of falling ore grades and rising costs [1], [2]. Innovative technologies, process automation and digitalization, as well as intensified optimization of equipment management, are identified levers for improving efficiency and reducing unit costs [3], [4], [5].

* Corresponding author: Ibrahima Kalil KOUROUMA

In Guinea, the Guinea Bauxite Company (CBG) is adopting new technologies to further improve the performance of its machines and achieve its production objectives. Thus, the pre-enrichment of bauxite before the Bayer treatment allows for better recovery of alumina and alumina lost in the red mud and the discharged residues, making the operation of the reduction process more efficient, as well as the quality of the extracted product [6].

Furthermore, the expenditures incurred for the technical and biological rehabilitation of the new mining sites restore the local flora and soil, ensuring the sustainability of operations and improving environmental compliance [7]. This dual approach primarily improves technical, economic, and environmental performance, as well as CBG's global position among the major producers and exporters of bauxite.

THE The WENCO program, an integrated suite for managing and optimizing mining fleets, offers real-time monitoring of loading and transport operations, enabling the centralized collection of performance data for a better resource allocation. Its putting in artwork and its dispatching algorithms have enabled a significant reduction in operating costs, improved production reporting, and an increase in the quality of the ore delivered, thanks to better equipment utilization and a reduction of waiting times for trucks and excavators [8].

The analysis of the integration of the WENCO system in optimizing mining performance at CBG could be based on the interpretation of certain key indicators in the WENCO database, including performance, availability, utilization, and actual operating time. Indeed, studies of other mines that have adopted WENCO, particularly iron mines, indicate a "dramatic" improvement in resource utilization, a significant reduction in truck and excavator waiting times, and optimized dispatching leading to lower operating costs and higher ore quality [8].

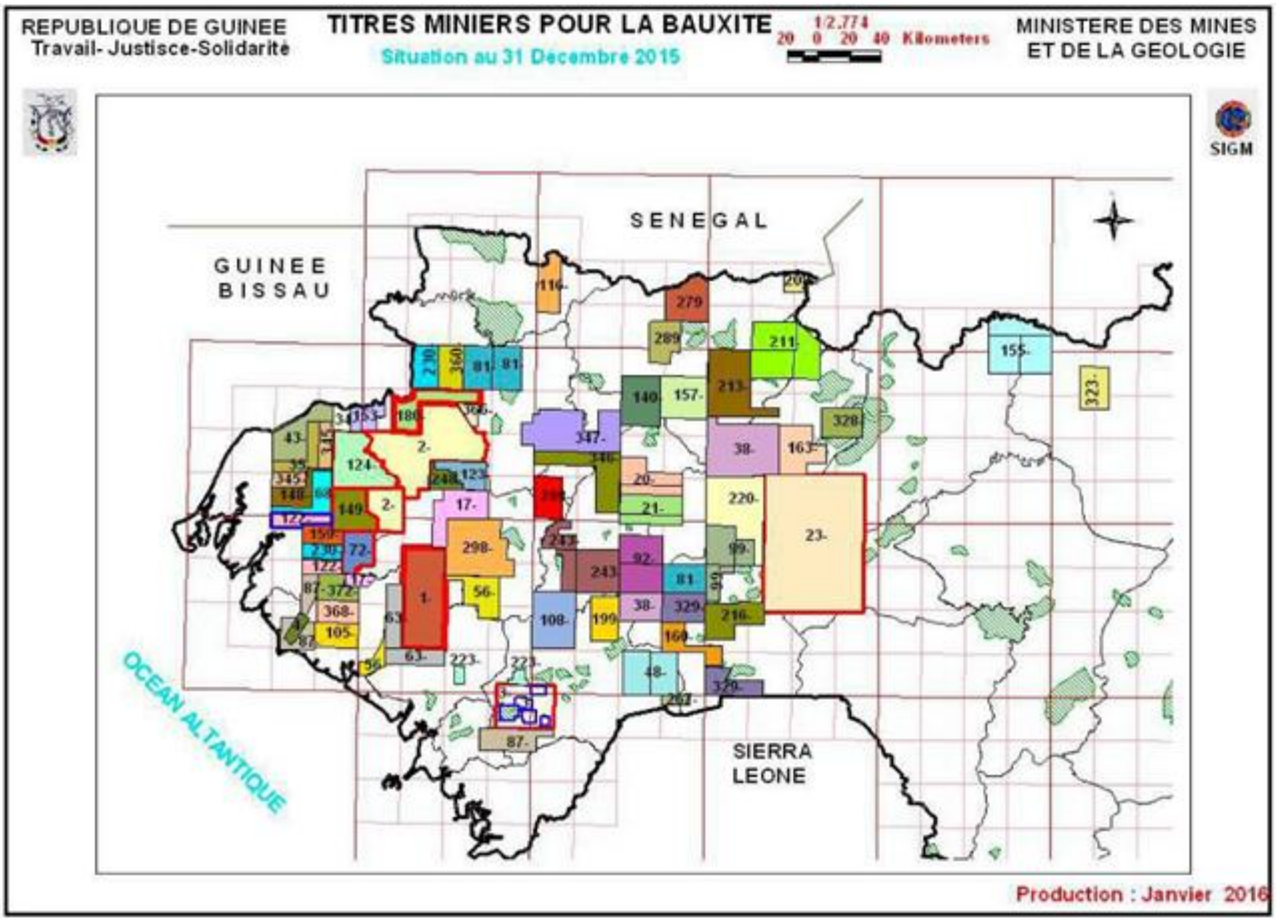
Analyzing real-time data allows for in-depth examination of the causes of production losses, providing a clear understanding of resource allocation to optimize the cost/quality ratio and identify areas for continuous improvement to ensure the competitiveness and sustainability of the mining industry. This underscores the importance of integrating the WENCO system into CBG's ongoing optimization process, where technology becomes a strategic driver of operational performance and the sustainability of Guinea's mining industry.

2. Material and methods

2.1. Study Site

The Guinea Bauxite Company (CBG) is the world's largest exporter of metallurgical bauxite. With mines located in the northwest of the Republic of Guinea, it exports over 14 million tons annually for alumina processing in plants throughout the Atlantic Basin. CBG is a company registered in the State of Delaware (United States of America), as well as in the Trade and Real Estate Credit Register of the Republic of Guinea, where it has its headquarters and all its production facilities. CBG operates the Sangarédi mine, located 138 kilometers from the port of Kamsar. [This text should be analyzed and improved to meet the requirements of the study site regarding the period covered.] Since 1973, CBG has exported 500 million tons of bauxite, generating over $5 billion in revenue for the Guinean government.

The Guinea Bauxite Company Concession (CBG) is located at little near the sub -prefecture of Sangarédi in the prefecture of Boké in Northwest Guinea, between 11°05'48' ' latitude North and 13°46'34'' West longitude. It is distant 135 kilometers northeast of Kamsar and 370 kilometers north of Conakry, the capital. The map in Figure 1 below shows the bauxite mining titles in Guinea.



Legend: Numbered coloured polygons: titles assigned for bauxite; Numbers within the blocks: identifier of the mining title (permit, concession, etc.); Different colours: distinction between the different mining companies holding the concessions. Scale: 1:2,774,000 ; Orientation: North arrow; Sources: Ministry of Mines and Geology / SIGM; Production date: January 2016

Figure 1 Map of the bauxite mining title in Guinea

The Republic of Guinea, possessing one of the world's largest bauxite deposits, organizes access to and exploitation of this strategic resource through the allocation of mining titles in the form of exploration permits and concessions. The map of "Mining Titles for Bauxite – Situation as of December 31, 2015" provides a clear illustration of the distribution of titles, which is concentrated in the Boké region. This bauxite basin has a diverse range of stakeholders, operating in a balance of competition and complementarity. Other titles are appearing in inland areas, reflecting a desire for diversification potential, while the absence of titles in other regions, particularly in the south and east, suggests either limited potential or a priority given to coastal areas closer to port infrastructure. As a national-scale map (1:2,774,000), it illustrates Guinea's geostrategic importance in the global bauxite trade and as an analytical tool, it is emblematic of the challenges of mining governance, economic dynamics and prospects for mining land management.

2.2. Equipment

2.2.1. Presentation of bauxite to CBG

Bauxite is a lateritic rock that constitutes the principal ore of aluminum when it is hardened or loose. It contains a large amount of alumina and its dull color varies from white to reddish-brown depending on a relative density between 2 and 2.55.

It is composed mainly of three minerals: Gibbsite ($Al2O3.3H2O$), Bohemite ($Al2O3.H2O$) and Diaspore ($Al2O3.H2O$).

In tropical environments, during the alternation of two seasons, the interstices of the Diaspore are filled by Bohemite , while in other regions, Bauxite may be formed from only two minerals, Gibbsite and Bohemite .

Genetic types

We distinguish three genetic types of bauxite in the HALCO concession:

- lateritic bauxites in – situ or residual;
- sedimentary lateritic bauxites;

Chemogenic bauxites (Gelified – Gelomorphic).

The distinguishing factors at a glance are the face, texture, and structure.

In-situ or residual lateritic bauxites

This type of bauxite is formed by the weathering of source rocks. The Paleozoic sedimentary source rocks are the Devonian Faro1 and Faro2 aleuro -argillites and the Mesozoic doleritic intrusions (dolerites). In-situ bauxites constitute 75% of the total reserves within the CBG territory.

The main facial features are as follows:

- Structural bauxites (Figure 2);
- Fragmentary bauxites; brecciated bauxites;

Skeletal bauxites (Figure 3);

Figure 2 Structural bauxite (source: CBG Prospecting section)

Figure 3 Skeletal bauxite (source: CBG Prospecting section)

Sedimentary lateritic bauxites

The sedimentary lateritic bauxites were formed by the weathering of sedimentary deposits accumulated in the Paleo-Cogon lake basin during the Middle Miocene. At that time, this region, occupied by a shallow sea, had become an area ofattraction and accumulation of sediments eroded from all horizons. Following tectonic movements that favored fracturing and uplift of the basin, erosion and denudation phenomena occurred throughout the region, thus removing a large portion of these deposits.

Now exposed to exogenous conditions, these deposits lying at an altitude of 240-260m began to disintegrate and alter,eventually becoming bauxitized wherever they were preserved, to be called today the "Sangarédi Series".

This is the case of the deposits of Sangarédi, Bidikoum Nord, Silidara Sud, Boundou Waadé and N'Dangara East. The basic topographic erosion level was the driving force behind the transport of deposits towards the ocean, which leads us to remark ironically that "we are behind the Sangarédi series deposits." Small deposits are found to the west (Parawi , Koobi , Bourorè , Wossou) and become increasingly rare as one moves away from the Sangarédi deposit. It is important to note that Sangarédi-type bauxite outcrops are found throughout the territory, even in North Cogon , and can often be misleading during geological surveys because in some places their thickness does not exceed 30 cm. The sedimentary lateritic bauxites, very rich in aluminum hydroxide (> 60%), have made the Sangarédi deposit the largest and richest bauxite deposit in the world, "unique."

The proportion of sedimentary lateritic bauxites in the CBG territory is 22% of the total reserves.

The main facial features are:

- Conglomeratic bauxites (Figure 4)
- Gravelly bauxites;
- Psammetic Bauxites;
- Silty bauxites.

Figure 4 Conglomeratic bauxite (source: CBG Prospecting section office)

Chemiogenic sedimentary bauxites

This genetic type is formed by recrystallization of a bauxite already formed of one of the two previous genetic types (residual or sedimentary of the Sangarédi series) thus undergoing an additional enrichment in alumina hydroxide. chemogenic bauxites in the CBG territory is 3% of total reserves.

The main facies of this type are:

- Gelified bauxites (Figure 5); Gelomorphic bauxites ;
- oolitic bauxites;
- Pisolitic bauxites.
- Gelified Bauxites, in which the structural and textual indices of the original rocks are partially preserved;

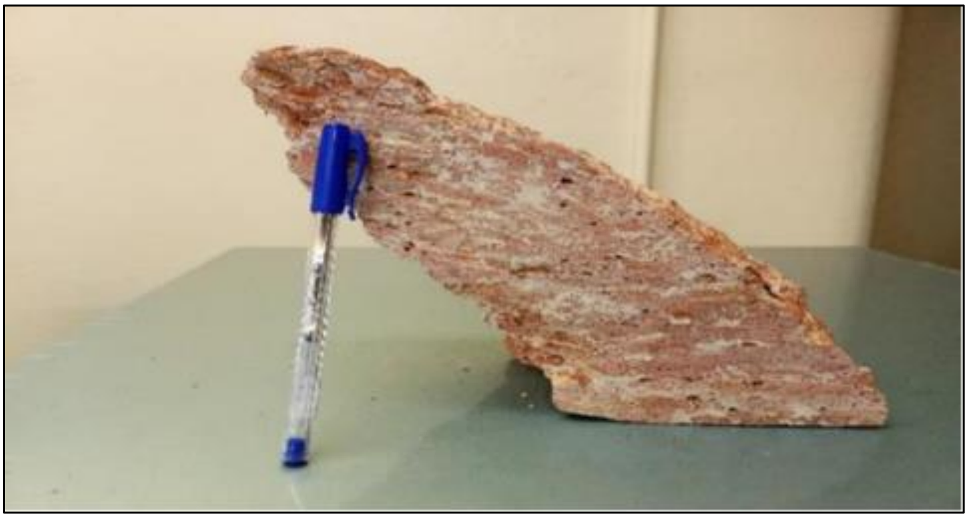


Figure 5 Gelatinized bauxite (source: CBG Prospecting section)

Gelomorphic bauxites (Figure 6) are entirely modified by the processes of redistribution and concentration of alumina. This facies is the result of advanced weathering in the Gley geochemical environment, characterized by iron deposition (leakage of iron) and frost weathering (alumina enrichment). Its texture makes it difficult to distinguish traces of the parent rock, as it is composed of gel, hence the name gelomorphic . It does not derive from a single genetic group; it simply represents the acute form of weathering.

Figure 6 Gelomorphic bauxite (source:CBG Prospecting section)

Oolitic bauxites (Figure 7) form nests, colloidal concretions resembling fish eggs, small blocks within sedimentary lateritic bauxites and gelomorphic bauxites . They are massive and compact.

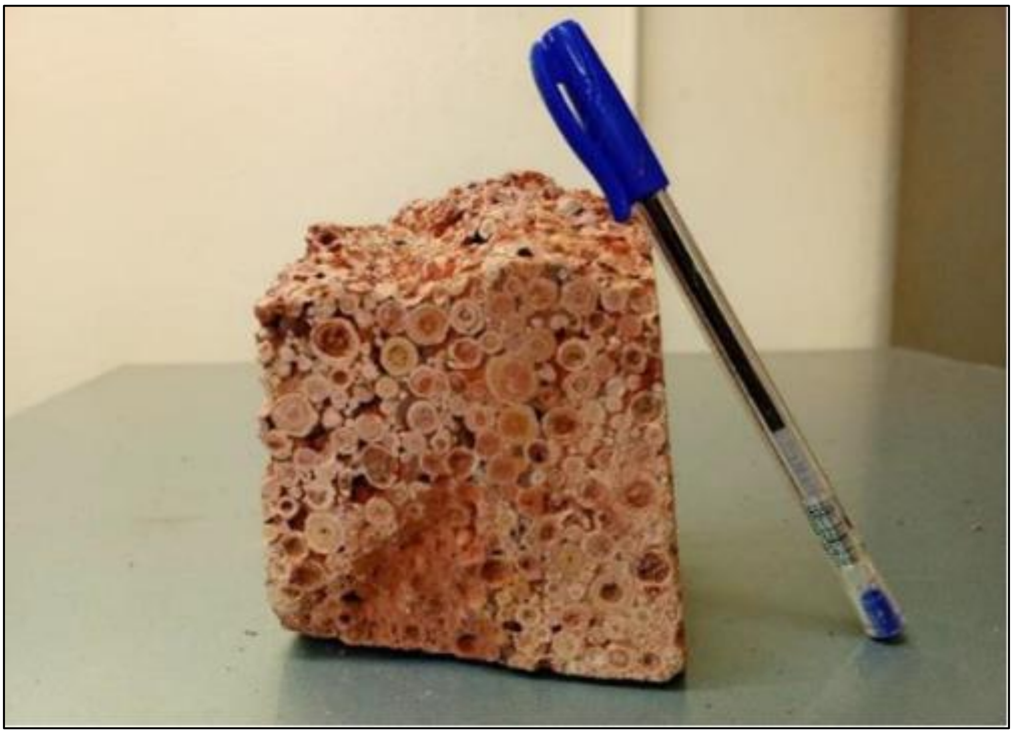


Figure 7 Oolitic bauxite (source: CBG Prospecting section)

Pisolitic bauxites: They form nests, larger concretions and small blocks within sedimentary lateritic bauxites and gelomorphic bauxites ; they are massive and compact.

2.2.2. Introduction to the Wenco system

The management of modern mining fleets relies crucially on open interoperability between asset health monitoring, advanced data analytics, and other technologies, undoubtedly enabling significant performance and safety gains while simultaneously limiting the social costs of routine operations. Intelligent management systems, integrating IoT, smart analytics , and open protocols, allow for the real-time collection and processing of data from multiple pieces of equipment and various manufacturers, thus facilitating rapid decision-making and optimal resource allocation [9], [10], [11] . The analysis of asset health data, particularly through the use of deep modeling, learning or prescriptive maintenance algorithms helps predict failures, optimize equipment availability and reduce unwanted downtime, and ultimately contributes to improving the performance and sustainability of mining operations [12], [13] .

Technological interoperability, facilitated by open systems and standardized APIs, is a prerequisite for the effective integration of solutions like WENCO, part of Hitachi Construction Machinery 's offering, in complex, multi-vendor environments. [10] , based on the centralization of data and the compatibility between different tools to constitute evolving digital ecosystems, capable of meeting the expectations of mining producers in terms of renewed efficiency, increased security, and lower operating and social costs [11].

Manufacturers are indeed making a significant contribution to the research and development of automation and its components, notably through the presentation of corresponding prototypes and the introduction of new capabilities to the market. Innovations are primarily organized around the integration of artificial intelligence, machine learning, sensory perception, path planning, and autonomous decision-making, all essential for the development of complex automated systems such as those performing heavy automation functions, like autonomous vehicles [14], [15] . These dynamics reflect a rapidly changing sector, where the ability to innovate quickly and offer robust solutions constitutes a major competitive advantage.

2.2.3. Components of the Wenco system

Wenco system includes both hardware and software components.

The hardware components:

Dispatch desktop computers, two Microsoft Windows servers, MDT (Mobile Data Terminal) onboard computers, Octagon RMB-C2, and communications equipment. Specific communications equipment required depends on mine requirements. Communications equipment may include: GPS antennas, GPS base stations, radio modems, repeaters, and Motorola Mesh wireless communication.

The software components:

Wenco applications (example: Fleet Control, Stockpile, Tir Max) and Wenco services to provide connections between Wenco applications and the system in real time.

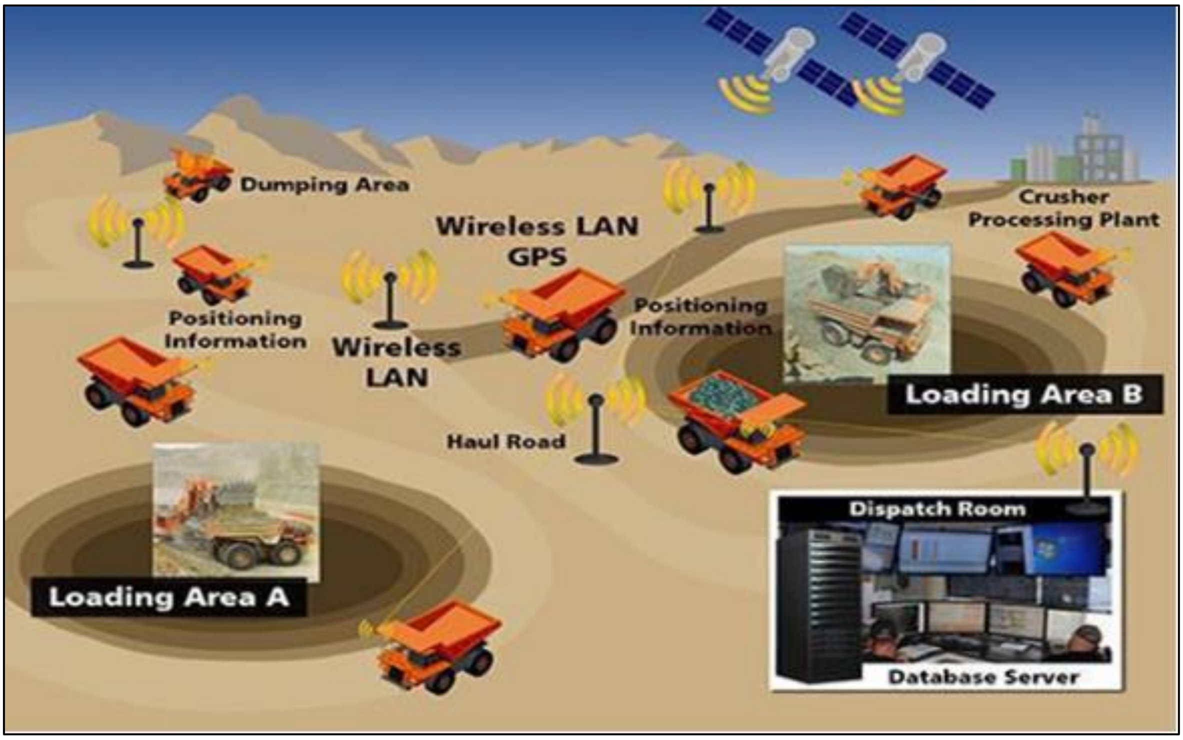


Figure 8 Wenco system works (Mining Magazine 2017)

2.2.4. Fleet Management

Fleet Control is the central software for assisting mine operators in the daily management of operations, as it enables the dynamic allocation of equipment, the real-time status and location of equipment, and the visualization of congested areas or units on standby. This type of system, by aggregating and analyzing operational data (location, status, fuel, engine hours, operator, etc.), allows supervisors to make immediate decisions to redeploy resources and reduce production losses, in line with the benefits expected from advanced fleet management implementations [9], [16] . Automatic dispatching (such as that offered by Wenco and presented in the chapter), which uses optimization and artificial intelligence algorithms, allows for the real-time allocation of transport and loading units according to several operational parameters (i.e., status, etc.), travel time, queues, etc., thus significantly improving equipment utilization and overall productivity [17] . However, recent studies indicate that combining technological elements such as computer vision, IoT, or artificial neural networks with dispatching systems also reduces waiting times, optimizes truck utilization, and increases performance while facilitating decision-making based on verifiable and up-to-date data [18] .

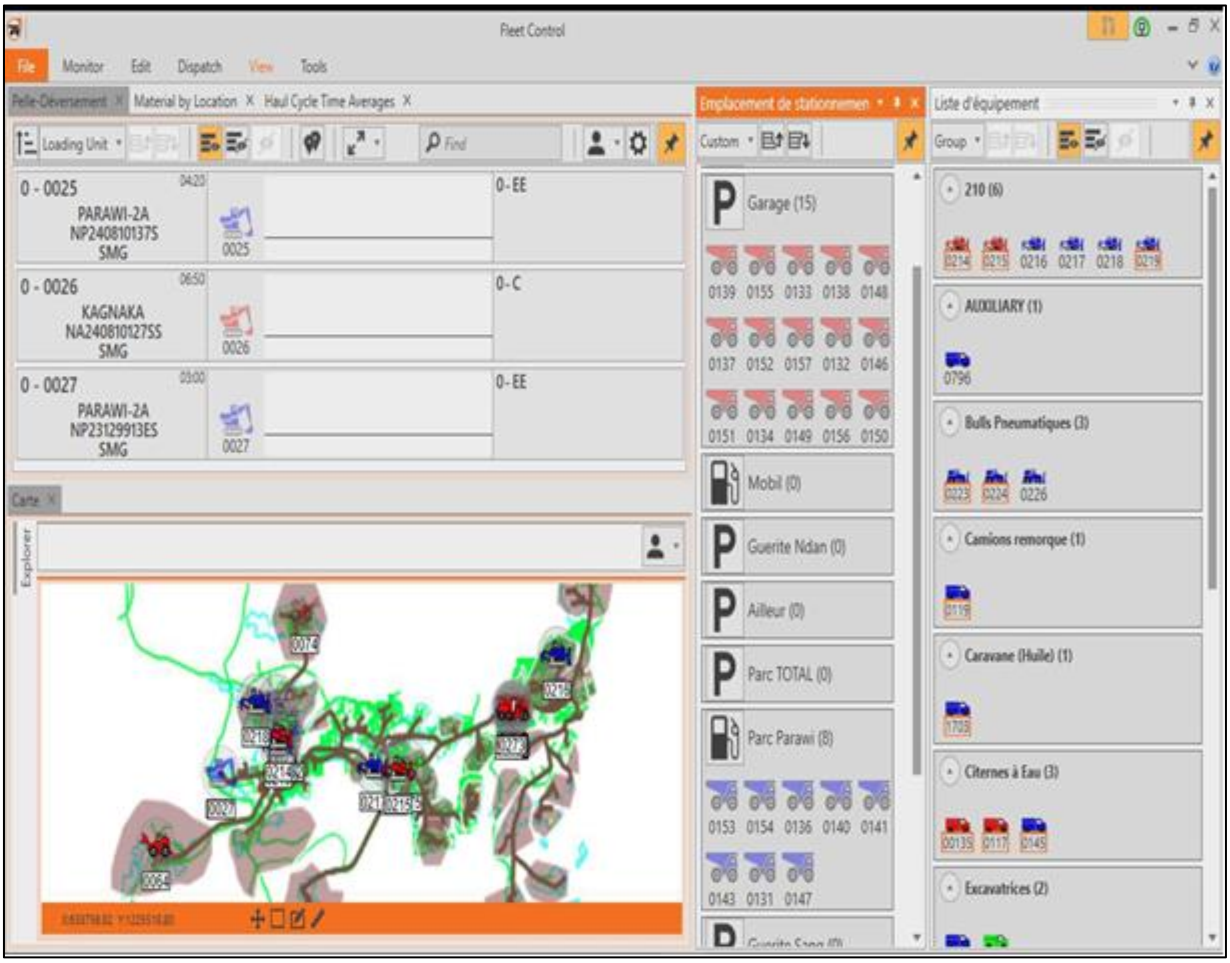


Figure 9 Fleet management

2.2.5. Bench Manager

The Bench Manager, as an in-cab application on a mobile data terminal (MDT), aligns with the trend of intelligent operator assistance systems in the mining industry. It provides real-time information, precise instructions, and visualization of design plans developed by planning, geology, and engineering departments, enabling operators to perform their work correctly and optimize operational accuracy [19], [20]. Similar devices, integrating sensors, cameras, and embedded user interfaces, facilitate operational guidance, equipment status monitoring, and performance analysis to improve safety, productivity, and energy efficiency [19]. The combination of digital models and in-cab assistance systems also contributes to data centralization and the transition to the digital mine, which facilitates decision-making and ensures compliance with production plans [20].

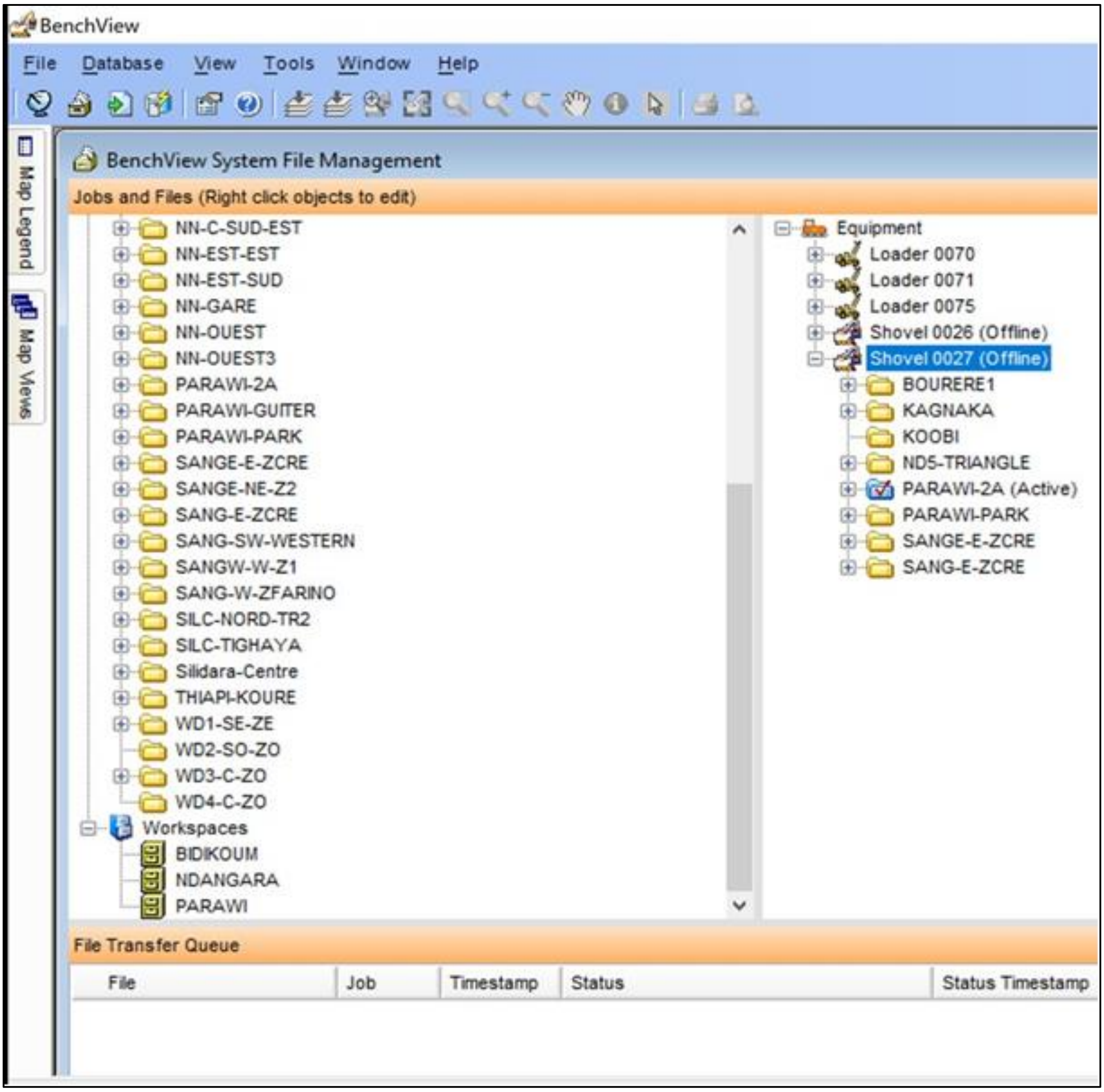


Figure 10 Bench View

2.2.6. Train/ Rare and Report Manager

The Train/Rame and Report Manager represents the solution for managing train transport, for tracking shipping parameters and train movement within the mine. Similar mining rail transport management systems are equipped with reliable, real-time information modules ensuring the accuracy and reliability of rail transport, including the centralization of information on train status, location, and schedules [21].

Optimization models and software tools are also used in viral scheduling, crew allocation, and worker workload management to contribute to job performance and human resource management in the mining sector [22]. It is important to remember that these applications contribute to the logistical coordination of operations, the reduction of human error, and the optimization of transport flows within the mine.

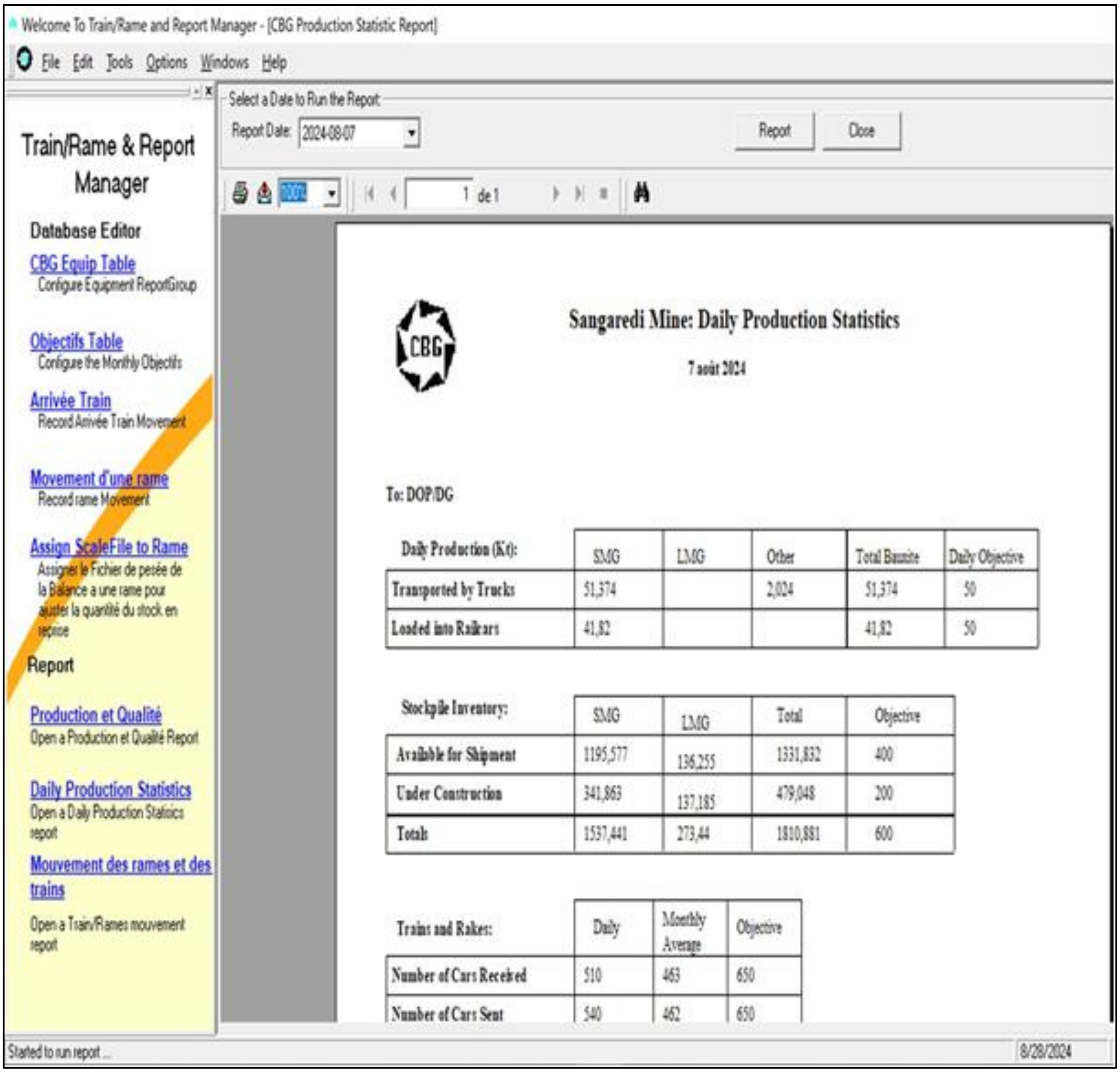


Figure 11 Train/Rail and manager report

2.2.7. Stock Pile Manager

Stockpile Manager is a mine stockpile management application that enables real-time monitoring of tonnage, quality, and current stockpile status using data from mine plans or laboratory analyses. Similar systems rely on high-resolution 3D models and GPS sensors to model stockpiles, track ore grade distribution, and adjust average grades in real time with each loading or unloading, thus contributing to the optimization of mixes and crusher feed planning [23], [24]. The integration of artificial intelligence and deep learning Machine learning, combining technological advancements, improves demand forecasting, optimizes raw material inventory management, and enables more precise monitoring of quality parameters, while reducing costs and increasing operational efficiency [25], [26]. Advanced machine learning algorithms, using 3D point cloud analysis, facilitate automatic volume measurement and scientific inventory management, thus enabling better traceability and a prompt response to meet grade range targets [27] in shortage situations. These innovations therefore offer solutions for efficient and reliable inventory management and a high degree of automation in the mining industry.

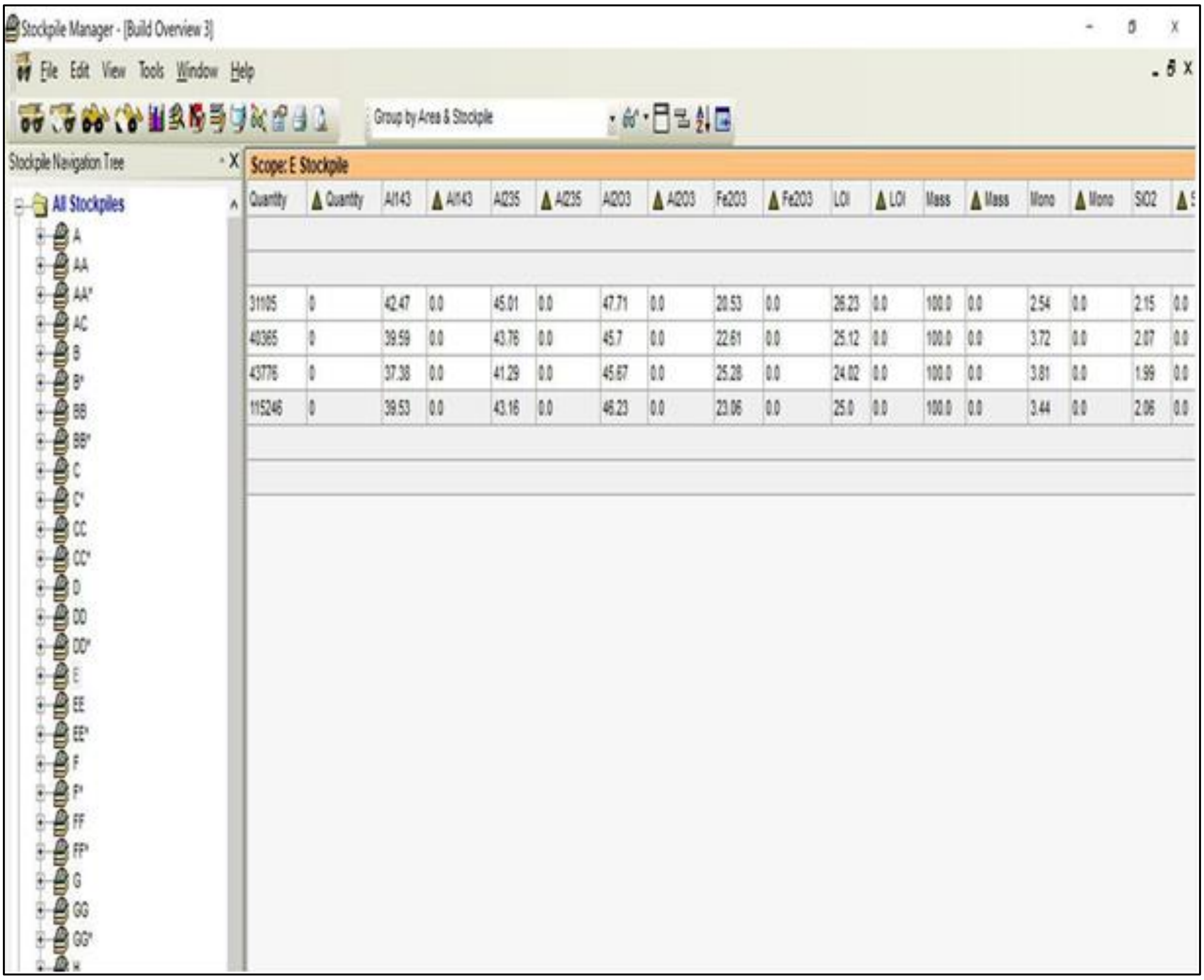


Figure 12 Stock pile manager

2.2.8. Wenco DB

Wenco system collects accurate data on mining operations daily through automation, eliminating the need for manual recording or error-prone human observation in data recording, monitoring, and processing. Automated data collection generates customized reports on operations and all aspects of production activity, while also improving visibility for managers to make informed decisions [8],[28].

Wenco solution offers operators, dispatchers, and application managers real-time access to mining data presented in simplified tables and graphs. This information is derived from various measurement methods, including truck-mounted scales and GPS, ensuring accurate tonnage measurement, spill geolocation, and numerous other operational data fo improved monitoring and management of mining operations [8].

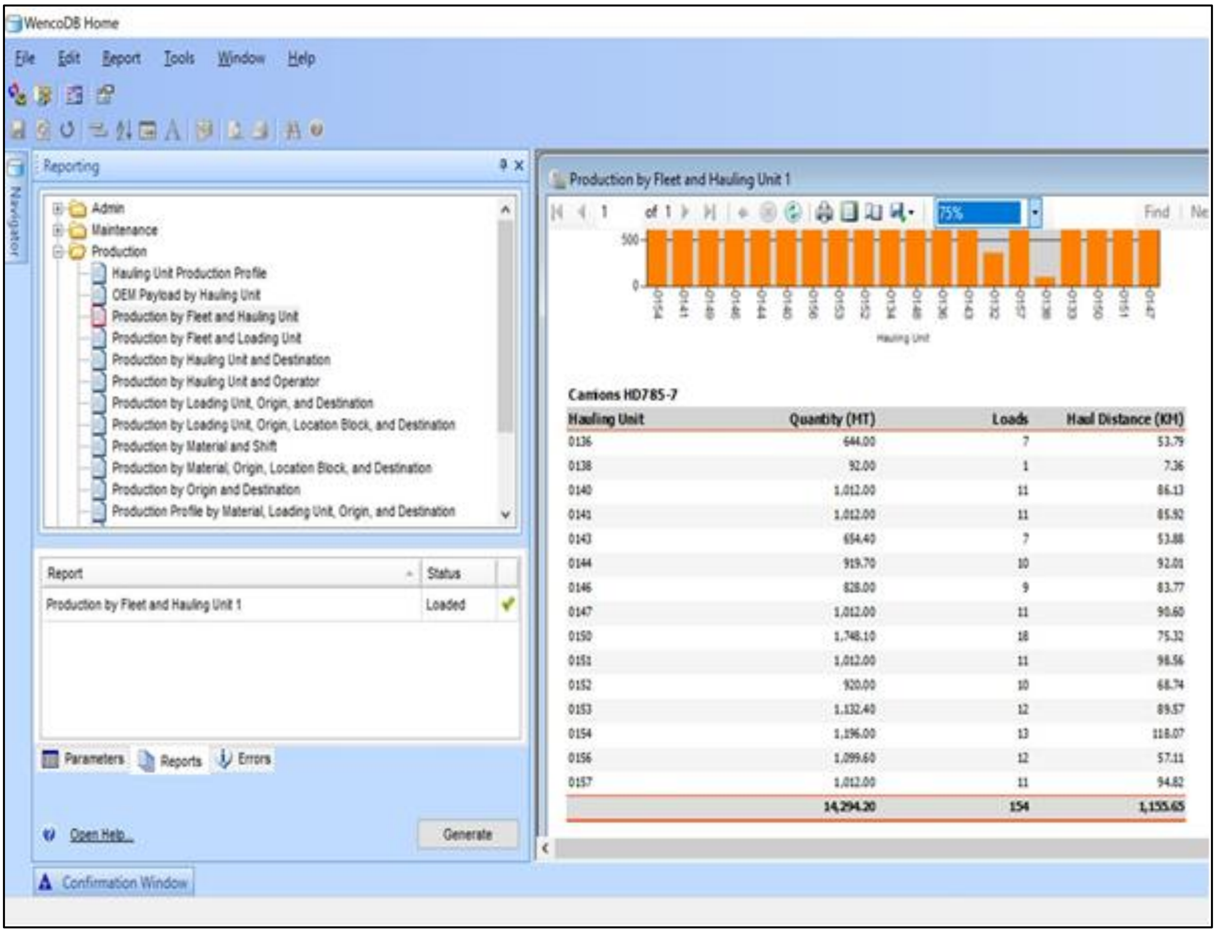


Figure 13 Wenco DB

2.3. Production Equipment

The production equipment within this field of study consists of the machinery used for loading and transport operations, namely: hydraulic excavators, loaders, and dump trucks. These two operations play a crucial role in mining due to their high cost and, even more so, the rigorous standards required for their daily execution, as all mining projects are evaluated based on the quantity of ore transported, also known as mine production.

Trucks and shovels (or excavators) are indeed the two most frequently used pieces of equipment in the mining sector, and their productivity is directly dependent on each other. In fact, when a problem arises with one of these two pieces of equipment, the output of the other will suffer: thus, if an excavator breaks down or operates slowly, the trucks sit idle, unable to load, generating a loss of productivity for the trucks; conversely, if there is a shortage of trucks, the excavators are idle. This interdependence results in waiting periods for the trucks (queues), or periods of inactivity for the excavators, which constitute opportunity costs leading to insufficient fleet utilization [29], [30.

2.3.1. Ding

Loading is a mining operation which the intention East to remove the spoil from the mining face using a transport vehicle, to a receiving point. Loading is one of the fundamental mining operations and is crucial to the success of any mining project because mine production depends almost entirely on the quantity of spoil loaded. It should be noted that it is more accurate to speak of spoil removal rather than loading. because mining operations depend on the chosen method of exploitation.

Figure 14 Loading with a Caterpillar loader (source: Sangarédi mine)

2.3.2. Loading equipment

Loading equipment is the equipment used to excavate the spoil from the mining face and place it into transport equipment for subsequent mining operations.

The choice of loading equipment is also crucial, as it directly impacts mine production. Several types of loading

equipment exist, each with its own capabilities and performance characteristics. The parameters used to measure this performance are:

- The bucket capacity;
- Cycle time; Penetration force;
- The height and depth of excavation;
- The height and radius of excavation;
- The height and radius of spillage;
- Mobility and availability.

2.3.3. Hydraulic excavators

Originally designed for public works projects, these machines have become essential in the mining industry thanks to their versatility, achieved through hydraulic transmission. The ability to work in a face or backhoe at various depths offers miners a range of technical solutions, making them a truly multi-purpose tool. Furthermore, their high penetration force and the bucket's digging motion frequently eliminate the need for blasting, resulting in a significant reduction in extraction costs. Finally, the precision and ease of maneuvering of the bucket, its level travel along the ground, and its ability to attack at the desired depth to break up material or clear a blast face are all factors that contribute to the development of these machines.

Table 1 Advantages and disadvantages of hydraulic excavators

Hydraulic excavators	
Benefits	Disadvantages
Short cycle times Can work in difficult conditions A good filling of the bucket	Not very mobile Very expensive to buy Sensitive to rock quality

At the CBG Sangarédi mine, the shovels used are KOMAT'SU models PC1800, PC2000 (backhoe and shovel) and are generally used on restricted sites where the movement of a loader is not possible or deep mines.

Figure 15 The 027Komat'su PC 2000 shovel in a mound (Source: Sangarédi mine)

Figure 16 Komat'su PC 2000 026 backhoe (Source : Sangarédi mine)

Table 2 Characteristics of shovels at the Sangarédi mine

Brand	**KOMAT'SU**	
Types	PC 1800 (Butte)	PC 2000 (Retro)
Weight (t)	180	200
Bucket capacity (m^3)	11.4	13.7

2.3.4. Pneumatic Loaders

A loader is a material handling machine consisting of a self-propelled, articulated body and a large bucket at the front. The loader's bucket is called a hopper when it is used to load materials into transport vehicles. Loaders are the most commonly used loading equipment in mining and quarrying operations.

Table 3 Advantages and disadvantages of loaders

Loaders	
Benefits	**Disadvantages**
Highly mobile Not very sensitive to the condition of the rock Can be used for auxiliary tasks Moderate purchase cost Can load large blocks	Long cycle time Limited loading height Very sensitive to soil conditions Tiring for the staff Poor visibility (reversing) Short lifespan

On site, the loaders used are of two types including three models: CATERPILLAR, models 992K and 988B and KOMAT'SU model KWA900.

Table 4 Types of loaders at the CBG mine

TYPES	**CATERPILLAR**		**KOMAT'SU**
MODELS	992K	988B	KWA900
WEIGHT (t)	99.831	43.365	116.4
BUCKET CAPACITY (m^3)	10.7-12.3	5.4	13

Figure 17 Caterpillar 992K type loader (Source: Sangarédi mine)

2.3.5. Transport

Transport from the quarry constitutes a very significant cost item in the mining process, representing 20 to 30% of the total cost according to the study by Djebari (2019). This substantial proportion of transport costs is confirmed by numerous studies which show that in open-pit quarries, transport costs can reach 35 to 50% of production costs depending on the depth of the quarry being mined and the distances to be covered to transport the ore, also depending on the mode of transport (trucks, loaders, convoys) chosen [31], [32].

At the Sangarédi mine, the extracted ore is loaded onto large trucks and transported to storage areas, where it is then sorted according to quality and quantity criteria. To reduce this residual cost, optimizing the allocation of transport equipment (trucks, loaders, etc.) and the choice of transport modes is essential for optimizing costs and operational efficiency [33]. Considerable cost savings of 13% or more can be achieved, particularly through optimization models or rationalization methods that reduce transport costs within the quarry by adapting the transport plan to its specific context.

2.3.6. Tansport Equipment

Transport vehicles are the vehicles that allow the ore to be moved from a loading point to an unloading point.

2.3.7. Dump Trucks

A dump truck is a self-propelled, wheeled vehicle with an open bed that transports, dumps, or spreads materials. Its main function is to move or transport raw materials such as soil, sand, rocks, and gravel.

Rigid Dump Trucks

This is a dump truck with two axles mounted on a fixed chassis. This is why this dump truck is described as rigid or sometimes fixed. The cab and the dump body are a single unit. Due to the lack of articulation, the turning radius of this dump truck is greater than that of an articulated dump truck. Those used on the site are from two (2) brands and include three models: KOMAT'SU (model HD 785-7) and CATERPILLAR (models 777F and 777G).

Figure 18 A rigid dump truck from the Sangarédi mine (Komat'su 785-7)

Identification of production equipment

The main production equipment at the Sangarédi mine are: hydraulic shovels, wheel loaders and dump trucks.

- Hydraulic excavators:

At the Sangarédi site we have three (03) hydraulic excavators of the same manufacturer, but of different models

Table 5 Types of hydraulic excavators on site

Manufacturer	Shovel No.	Models	Nominal bucket capacity (m^3)
KOMAT'SU	025	PC - 1800	11.4
	026	PC - 2000	13.7
	027	PC - 2000	13.7

- Pneumatic loaders:

Komat'su loaders,

Table 6 Types of pneumatic loaders on site

Loader No.	Types	Model	Nominal bucket capacity (m^3)
Caterpillar	062	992K	10.7 – 12.3
	063		
	064		

- Rigid dump trucks

We have twenty-five (25) rigid dump trucks on site

Table 7 List of dump trucks on site

Types	Truck No.	Model	Nominal capacity of the skip (m3)	Nominal useful capacity (t)
Caterpillar	131	777F	60	98.5
	132			
	133			
	134			
	138	777G	64.1	195.172
	139			
Komat'su	136	HD 785	60	91
	137			
	138			
	139			
	140			
	141			
	142			
	143			
	144			

3. Methods

The goal of optimizing the productivity of production equipment is to increase availability and utilization in order to maximize production.

For this study, the working methodology used is analytical and is based on a diagnosis of the productivity of production equipment.

- Approach to optimizing the productivity of production equipment:
- Identification of the main production equipment;
- Ratio between the nominal capacity and the actual capacity of production equipment;
- Calculating the performance for each machine;
- Calculating the availability of each piece of equipment;
- Calculating the usage for each machine;
- Actual operating time;
- Performance < 95% to be analyzed;
- Pareto of causes;
- Reasons accepted;
- Contributing solutions;

3.1. Analysis parameters used

The parameters for analyzing the optimization of production equipment productivity in our study are: the nominal capacity of the equipment, the capacity achieved, availability, utilization, performance and actual operating time.

3.1.1. The nominal capacity

The nominal capacity of a machine is the maximum load value authorized by the manufacturer; it must be indicated on a technical data sheet.

At CBG, the contractual capacity of the production equipment is:

- 90-92 T for hydraulic excavators
- 90-92 T for Caterpillar type pneumatic loaders
- 82 T for Komatsu type loaders
- 90 T for Caterpillar type dump trucks
- 91T for Komatsu type dump trucks

3.1.2. The capacity achieved

Wenco system database.

3.1.3. Performance calculation

Performance is the quantity produced during operating time relative to the theoretical capacity of the equipment (Koch, 2023). Calculating performance allows us to determine whether the equipment is being used rationally or not.

$$PR = \frac{\textbf{ACTUAL CAPACITY}}{INSTALLED\ CAPACITY} \times \mathbf{100}\ ;\ \mathbf{(1)}$$

Where PR = performance

3.1.4. Calculating availability

Availability is the ability of equipment to be in a state to perform a required function under given conditions at a given time or during a given time interval. Availability is calculated as follows:

$$\mathbf{D} = \frac{\textbf{ACTUAL OPERATIONAL TIME}}{\textbf{PLANNED TIME}} \times \mathbf{100}\ ;\ \mathbf{(2)}$$

Where D = Availability

4. Results and discussion

4.1. Ratio between nominal capacity and actual capacity

The processing and analysis of organic data from the WENCO system reveals a significant gap between the theoretical capabilities of machines, such as those of the Komatsu PC2000 hydromechanical excavator, and actual performance levels, which remain below 95%. Part of this discrepancy stems from the manipulations experienced by the machines, such as unplanned stops, extended cycle times, and/or underfilling of buckets, as the same effects have been observed in other studies on excavator productivity [34].

The emergence of precise assessments of work cycles and determinations of the causes of a loss of performance is achieved through the collection and fusion of multidimensional data (sensors, GPS, hydraulic pressures, etc.) which allows for a better understanding of operational states, as well as better optimization of the use of equipment [35].

The use of more advanced methods such as automatic work cycle recognition, or productivity analysis from real-time data, makes it possible to improve the accuracy of monitoring, to understand the sources of inefficiency and to consider performance gains, as well as better management of stops and [36].

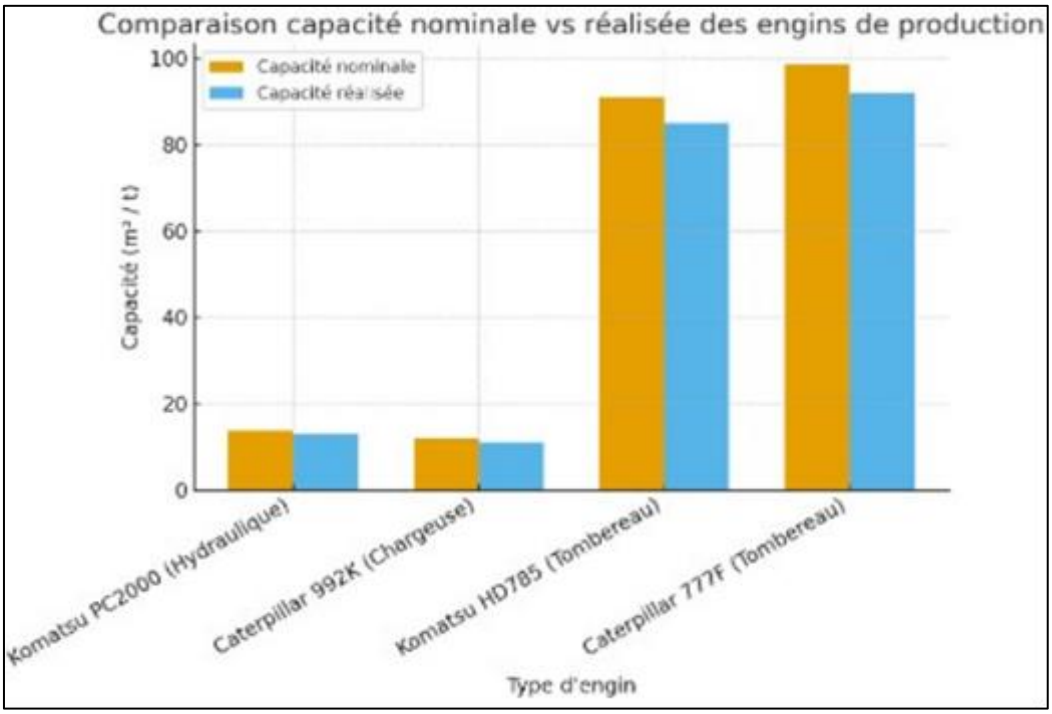


Figure 19 Nominal capacity and actual production capacity

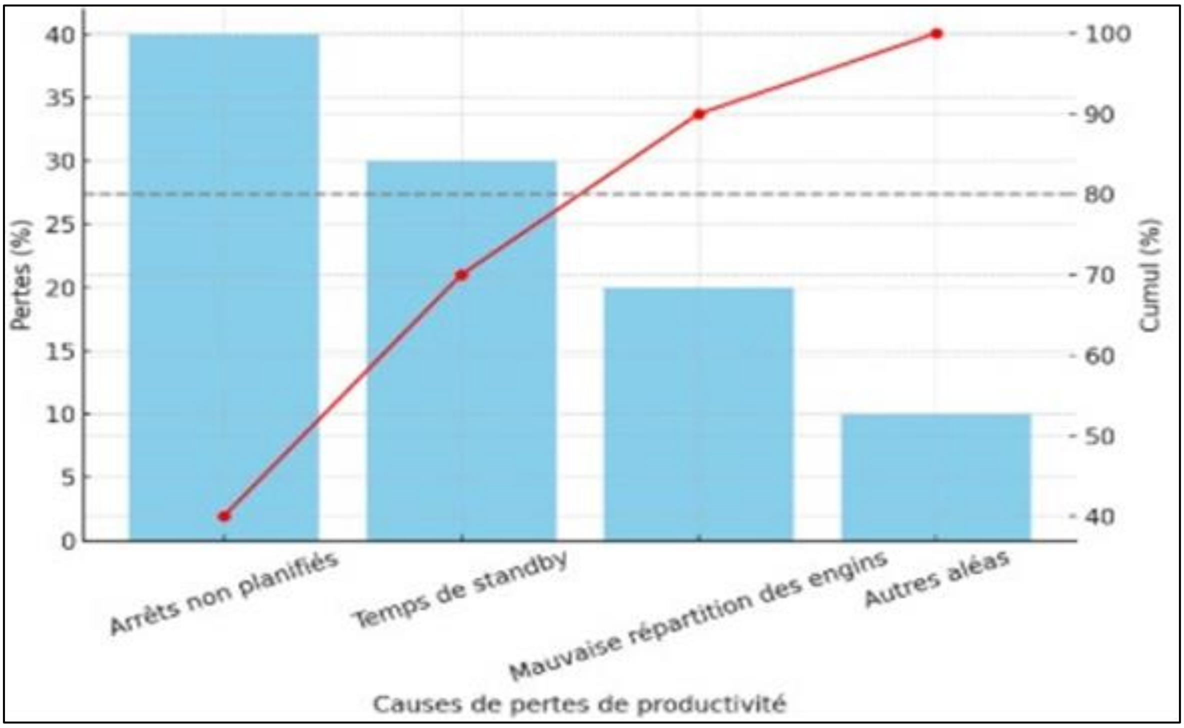


Figure 20 Pareto chart of the causes of productivity losses

4.2. Performance of production equipment

Performance, calculated as the ratio of actual capacity to installed capacity, varies considerably from one machine to another. The results show that some Caterpillar 777F dump trucks achieve performance close to 98%, while others show values below 90%. These discrepancies reflect heterogeneity in machine operation and haul cycle management. These results highlight that performance depends not only on the equipment's technical characteristics but also on the quality of its operation.

4.3. Availability and use of equipment

Production machines are available, on average, at less than 85% of the target (CBG), with the observed rate varying depending on the type of breakdown (mechanical), the type of maintenance (planned), and operational contingencies, etc. Furthermore, machines with higher availability rates suffer from long standby times due to an imbalance between the number of trucks and the loading capacity of the excavators, contributing to a low utilization rate. The determining factor for performance would be the proper synchronization between transport and loading units.

4.4. Actual Operating Time (TOR)

The actual operating time (TOR) delivered by the WENCO system is located the underutilization of equipment. In several cases, the TOR is less than 70% of the planned time. This confirms the bad Operational cycle management. In Compared with other open-pit mines, gains of 10 to 15% are possible thanks to better optimization of distributions and better preventive maintenance.

4.5. Analysis of the causes of productivity losses

The assessment using the Pareto approach made it possible to identify all the causes of a loss of productivity:

- Unplanned machine shutdowns related to safety defects (mechanical failures);
- Waiting time due to a faulty balance between transport units/lightweights and loading units;
- Poor reassignment of equipment due to poor WENCO system configuration.

These results confirm that the condition of implementing a fleet management system is not sufficient to guarantee its performance, which is dependent on the quality of the input data, the configuration and the real-time monitoring by operators.

4.6. General Discussion

In general, this study shows that the integration of the WENCO system into CBG, in spite of its improvements productivity, a Again This generated a deficit of nearly 198,000 tons compared to the 2022 annual target . justifies the strengthening of preventive maintenance, the link between the equipment and the training related to the use of the system. These results appear crucial in mining optimization. They indeed evoke the importance of a link between technology, organization and human management.

5. Conclusion

Studies have shown that the WENCO system and similar fleet management systems are a key driver for operational profitability. Indeed, this system enables increased productivity, optimized operational efficiency, and improved ore quality, all while reducing costs and errors. Integrating these tools into a comprehensive performance management strategy is essential to maximizing the aforementioned benefits.

Analysis of the impact of the WENCO system on the productivity and efficiency of production equipment at CBG shows that it could be a significant lever for optimizing mining operations. Indeed, by enabling real-time monitoring of loading and transport cycles, optimizing equipment allocation, and reducing waiting times, it improves the performance of the entire process.

Even with advanced management tools, the actual performance of dump trucks often remains below the installed capacity, mainly due to environmental, organizational, and reliability factors. Preventing the degradation of operating conditions is essential to limiting discrepancies.

The analyses conducted confirm that while technology is undeniably essential in this field, it cannot be the sole guarantor of mining productivity. Indeed, managing unplanned downtime, waiting times, and suboptimal allocation requires proactive management based on human synergy to best organize the daily management of events likely to maximize equipment performance.

To ensure the success of the WENCO system, it is necessary to use a state-of-the-art maintenance service, appropriate configuration, and continuously trained teams. These levers meet the requirement to move from installation capacity to actual capacity in order to achieve production objectives. The choice of WENCO type systems is part of a sustainability approach aimed at reconciling increased mining productivity and reduced environmental impact, but it must be integrated into a system approach of optimization and innovation.

References

[1] J. Ndhlovu and P. Chileshe, “Global Mine Productivity Issues: A Review,” International Journal of Engineering Research and , vol. 9, May 2020, doi : 10.17577/ijertv9is050071.

[2] D. Humphreys, “Mining productivity and the fourth industrial revolution”, Mineral Economics , vol. 33, p. 115-125, Feb . 2019, doi :10.1007/S13563-019-00172-9.

[3] S. Ahmad, “Innovation and Drivers of Productivity: A Global Analysis of Selected Critical Minerals,” Commodities Nov. 2023, doi : 10.3390/commodities2040024.

[4] SS Rai, V. Murthy, N. Sukesh, AS Teja, and S. Raval , “Operational efficiency of equipment system drives environmental and economic performance of surface coal mining—A sustainable development approach,” Sustainable Development , Sept. 2020, doi : 10.1002/SD.2129.

[5] M. Onifade , J. Adebisi, AP Shivute , and B. Genc , “Challenges and applications of digital technology in the mineral industry,” Resources Policy , August 2023, doi : 10.1016/j.resourpol.2023.103978.

[6] MC Béavogui , B. Balmaev , O. Kaba , A. Konaté , and I. Loginova, “Bauxite enrichment process (Bayer process): Bauxite cases from Sangaredi (Guinea) and Sierra Leone”, PROCEEDINGS OF THE 16TH INTERNATIONAL CONFERENCE ON INDUSTRIAL MANUFACTURING AND METALLURGY (ICIMM 2021) , Jan. . 2022, doi :10.1063/5.0074812.

[7] I. Kourouma, O. Hawa, A. Bah, G. Soryba , and Bangoura , “Study of certain technical aspects of the rehabilitation of bauxite mining sites operated at the Sangarédi mine (Parawi deposit, Compagnie des Bauxites de Guinée mining concession; CBG)”, World Journal of Advanced Research and Reviews , Feb. 2023, doi : 10.30574/wjarr.2024.21.2.2667.

[8] K. Kangwa and V. Mutambo , “Application of High Precision Mining for Optimizing Load and Haul Operations at Kansanshi Mine, Zambia,” Journal of Natural and Applied Sciences , Dec. 2022, doi : 10.53974/unza.jonas.6.1.524.

[9] M. Farahpoor , O. Esparza, and M. Soriano, “Comprehensive IoT-Driven Fleet Management System for Industrial Vehicles,” IEEE Access , vol. 12, p. 193429-193444, 2024, doi : 10.1109/ACCESS.2023.3343920.

[10] H. Bnouachir , M. Chergui , M. Zegrari , A. Chakir , L. Deshayes , and H. Medromi , “Smart Fleet Management System Based on Multi-agent Systems: Mining Context”, Advanced Intelligent Systems for Sustainable Development (AI2SD'2020) , Jan. 2022, doi :10.1007/978-3-030-90639-9_62.

[11] R. Marin, “Telemetry: connectivity and productivity in real time - project implementation guide”, MassMin 2020: Proceedings of the Eighth International Conference & Exhibition on Mass Mining , Jan. 2020, doi :10.36487/ acg_repo /2063_102.

[12] L. Liao and H.-I. Ahn, “Combining Deep Learning and Survival Analysis for Asset Health Management,” International Journal of Prognostics and Health Management , Nov. 2020, doi : 10.36001/ IJPHM.2016.V 7I4.2458.

[13] S. Patil, A. Mitra, KT Katarikonda , and J.-D. Wansink , “Predictive asset availability optimization for underground trucks and loaders in the mining industry”, OPSEARCH , vol. 58, p. 751-772 , Jan. 2021, doi :10.1007/s12597-020-00502- 4.

[14] J. Zhao et al. , “Autonomous driving system: A comprehensive survey”, Expert Syst. Appl. , flight. 242, p. 122836, Dec . 2023, doi : 10.1016/j.eswa.2023.122836.

[15] L. Ullrich, M. Buchholz, K. Dietmayer , and K. Graichen , “Expanding the Classical V-Model for the Development of Complex Systems Incorporating AI,” ArXiv , vol. abs/2502.13184 , Feb. 2025, doi : 10.1109/TIV.2024.3434515.

[16] K. Hasözdemir , M. Meral , and M. Kahraman , “Revolutionizing Open-Pit Mining Fleet Management: Integrating Computer Vision and Multi-Objective Optimization for Real-Time Truck Dispatching,” Applied Sciences , Apr. 2025, doi : 10.3390/app15094603.

[17] M. Afrapoli , S. Upadhyay, and H. Askari- Nasab , “A nested multiple-objective optimization algorithm for managing production fleets in surface mines,” Engineering Optimization , vol. 56, p. 378-391, Dec . 2022, doi : 10.1080/0305215X.2022.2153840.

[18] D. Huo, YA Sari, and Q. Zhang, “ Smart dispatching for low-carbon mining fleet: A deep reinforcement learning approach,” Journal of Cleaner Production , Jan. 2024, doi : 10.1016/j.jclepro.2023.140459.

[19] M. Ramezani and S. Tafazoli , “Using Artificial Intelligence in Mining Excavators: Automating Routine Operational Decisions,” IEEE Industrial Electronics Magazine , vol. 15, p. 6-11, March 2021, doi : 10.1109/MIE.2020.2964053.

[20] A. Strange and Z. Jecny , “Development of Digital Subterranean Models for Real-Time Open Cut Horizon Control,” Resources , Apr. 2020, doi : 10.3390/resources9040050.

[21] L. Ming-Yin, “Reliability design of information system for mine train transport management”, Industrial Minerals and Processing , Jan. 2006, [Online] . Available at: https://consensus.app/papers/reliability-design-of-information-system-for-mine-train-ming-yin/64081a35224352aaa9bcf01511fa829d/

[22] J. Amaya, E. Molina, N. Morales, and P. Uribe, “Optimization model for rostering and crew assignment for train transportation,” Mining Goes Digital , May 2019, doi : 10.1201/9780429320774-48.

[23] M. Yaqot , R. Franzoi , A. Islam, and B. Menezes, “Cyber-Physical System Demonstration of an Automated Shuttle-Conveyor-Belt Operation for Inventory Control of Multiple Stockpiles: A Proof of Concept,” IEEE Access , vol. 10, p. 127636-127653, 2022, doi : 10.1109/ACCESS.2022.3226942.

[24] S. Zhao, T.-F. Lu, L. Statsenko , B. Koch, and C. Garcia, “A framework for near real-time ROM stockpile modeling to improve blending efficiency,” Journal of Engineering, Design and Technology , July . 2021, doi : 10.1108/jedt-12-2020- 0541.

[25] Ö. A. Ünal , B. Erkayman , and B. Usanmaz , “Applications of Artificial Intelligence in Inventory Management: A Systematic Review of the Literature,” Archives of Computational Methods in Engineering , vol. 30, p. 2605-2625, Feb . 2023, doi :10.1007/s11831-022-09879-5.

[26] S. Sheela et al. , “Enhancing Stockpile Management Through Deep Learning with a Focus on Demand Forecasting and Inventory Optimization”, 2024 International Conference on Recent Advances in Science and Engineering Technology (ICRASET) , p. 1-6, Nov. 2024, doi : 10.1109/ICRASET63057.2024.10895608.

[27] X. Yang, Y. Huang, and Q. Zhang, "Automatic Stockpile Extraction and Measurement Using 3D Point Cloud and Multi-Scale Directional Curvature," Remote. Sense. , flight. 12, p. 960, March 2020, doi : 10.3390/rs12060960.

[28] Y. Nakagawa, "Mine production optimization using surface mining equipment monitoring systems", Jan. 2005, doi :10.14264/329657.

[29] SM Pathan, AG Pathan, and MS Memon, "Simulation Optimization of Shovel-Truck System in Open-Pit Mines Considering Rockmass Parameters," Journal of Advanced Transportation , Jan. 2025, doi :10.1155/ atr /7939037.

[30] B. Özdemir and M. Kumral , "Simulation-based optimization of truck-shovel material handling systems in multi-pit surface mines", Simul. Model. Pract . Theory , vol. 95, p. 36-48, Sept. 2019, doi : 10.1016/J.SIMPAT.2019.04.006.

[31] N. Kyrylenko, V. Shamrai , L. Kovalevych , M. Leblya , and A. Makhno , "JUSTIFICATION OF TRANSPORT WORKS IN THE CONDITIONS OF A BLOCK QUARRY," p. 14-23, May 2021, doi : 10.20535/2707-2096.5.2021.230667.

[32] A. Zhuravlev, "The issues of optimization parameters of quarry transport systems", p. 583-601, March 2020, doi : 10.25018/0236-1493-2020-31-0-583-601.

[33] K. Shah and S. Rehman, "Modeling and Optimization of Truck-Shovel Allocation to Mining Faces in Cement Quarry," Journal of Mining and Environment , vol. 11, p. 21-30 , Jan. 2020, doi : 10.22044/JME.2019.8329.1712.

[34] H.-Z. Song, G. Li, X. Xiong, M. Li, Q. Qin, and P. Mitrouchev , "A novel data fusion based intelligent identification approach for working cycle stages of hydraulic excavators. », ISA transactions , March 2024, doi : 10.1016/j.isatra.2024.03.006.

[35] J. Cui, D. Zhang, G. Zhu, Y. Wang, and K. Zou, " Spatio -Temporal Data Fusion-Based Method for Working Cycles Identification of Hydraulic Excavators," IEEE Transactions on Instrumentation and Measurement , vol. 74, p. 1-14, 2025, doi : 10.1109/TIM.2025.3545514.

[36] C. Chen, Z. Zhu, and A. Hammad, "Automated excavators activity recognition and productivity analysis from construction site surveillance videos," Automation in Construction , vol. 110, p. 103045 , Feb. 2020, doi : 10.1016/j.autcon.2019.103045.