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Analysis of Factors Affecting the Performance of Loading Equipment at the Sangarédi Mine (CBG Concession)

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ABSTRACT

Mining production involves a series of coordinated activities aimed at exploiting mineral resources in accordance with a predefined production plan. In bauxite mining, loading and transportation operations play a critical role in achieving production targets safely and at minimum cost. However, the performance of loading equipment can be affected by several technical and operational factors.This study focuses on analyzing the factors that influence the performance of loading equipment at the Sangarédi bauxite mine operated by the Compagnie des Bauxites de Guinée (CBG). The research was motivated by operational constraints observed in different mining plateaus, particularly time losses during bauxite loading by loaders and excavators.The methodology consisted of identifying and analyzing key performance indicators using statistical and analytical approaches, supported by bibliographic research, field observations, and production data processing. The main indicators considered include bucket capacity, loading cycle time, bauxite density and particle size, operator experience, machine performance, and various time components such as planned, available, effective working, and repair times.The results show that the practical annual production capacity of the loading equipment at the Sangarédi mine is estimated at approximately **15.9 million tonnes of bauxite**. However, for a semi-annual production target of **9.86 million tonnes**, the actual production reached **9.28 million tonnes**, despite only eight excavation machines being operational. Overall, the findings indicate that while the loading equipment is generally well utilized, improvements in equipment management and operational efficiency could help reduce production losses and better meet planned targets.

Keywords*:* Loading equipment performance, Bauxite mining, Productivity, Cycle timeKey performance indicators, Sangarédi mine (CBG)

INTRODUCTION

Guinea has considerable mineral wealth, attracting both industrialists and artisans to exploit its resources. The country's bauxite reserves, which have only been partially explored, are estimated to exceed 10 billion tonnes, making Guinea the world leader in bauxite. The main deposits are located in three geographical areas: Boké-Gaoual and Kindia-Fria in Lower Guinea, Dabola in Upper Guinea and Tougué in Middle Guinea. Among these areas, Boké-Gaoual, which accounts for about two-thirds of the national reserves, has the largest reserves [1]. In the Boké region, bauxite is found on easily accessible plateaus, with layers approximately 8 metres thick and almost entirely free of waste rock. The coastal ecosystem is home to four mining ports and numerous mining sites. Industrial mining activities exert considerable pressure on wildlife, flora, freshwater resources and soil in these prefectures. They disturb the land, destroy vegetation, degrade landscapes and affect agricultural land, while dumping red sludge into watercourses. This slurry clogs rivers, streams and ponds, causing pollution and difficulties in accessing drinking water due to the constant turbidity of water bodies, posing serious threats to the survival of biodiversity and local populations [1]. Mining consists of a set of operations primarily aimed at generating profits. Optimising these indicators requires rational use and careful monitoring of equipment.

The mining production chain often suffers from poor machine performance, often caused by repeated breakdowns, misuse of machinery, not to mention factors such as fragmentation resulting from blasting and climatic conditions [2]. That is why, during this internship period, a rigorous evaluation of the loading units and a systematic analysis of various factors and indicators will be at the heart of our study. Will these indicators aim to improve performance or evaluate the efficiency of the loading equipment used by CBG to achieve planned production? To answer this question, we have chosen to explore the theme: 'Analysis of factors influencing the performance of loading equipment at the Sangarédi mine, concession (CBG)'. This study aims to examine the various elements that impact the performance of excavators. The objective of this article is to identify performance indicators and analyse the factors influencing the production of excavation equipment. It consists of three (3) sections: The first section presents the general context of the study area and discusses concepts related to mining activities. The second section focuses on the equipment used and the methodology applied to carry out this study. Finally, the third section presents the results obtained and their analysis. **I.1 Cadre général et local du secteur d'étude.**

I.1.1 Geographical context

The prefecture of Boké, located between 10°30' and 11°45' north latitude and 13°45' and 15° west longitude, covers an area of 11,453 km² in the north-western region of Guinea. It is bordered to the northeast and east by the prefectures of Télimélé and Gaoual, while to the west it faces the Atlantic Ocean and to the south it borders the prefecture of Boffa [3]. The CBG's bauxite deposits, which are the subject of our study, are located in the sub-prefecture of Sangarédi, in north-western Guinea. This area is bordered:

- To the east by the sub-prefecture of Missira (prefecture of Télimélé);

- To the west by the prefecture of Boké;

- To the south by the sub-prefecture of Wedoubourou (prefecture of Gaoual).

The sub-prefecture of Sangarédi is located at a latitude of 11°16'00'“ North and a longitude of 13°46'00”' West, and covers an area of 2,537 km². Its geographical position is illustrated in Fig.

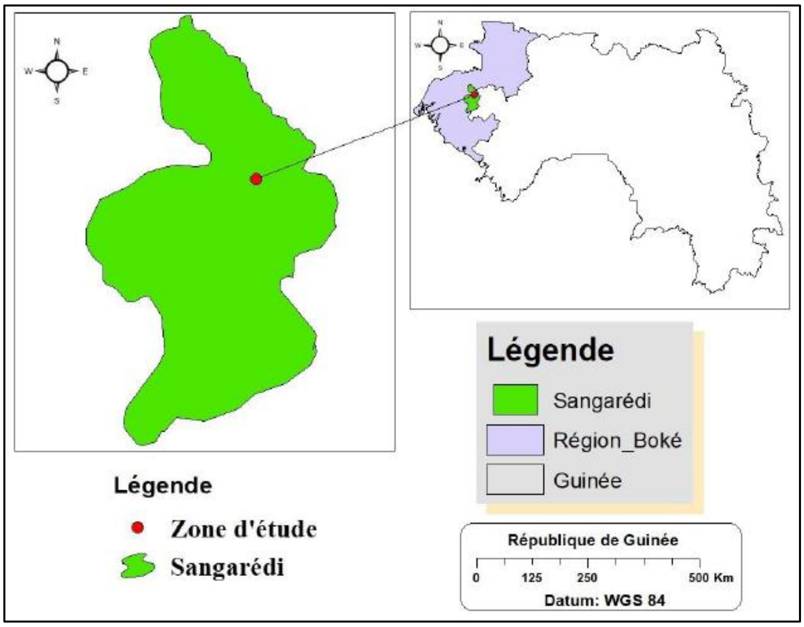

Figure 1: Location of the study area **[4]**

Population: Boké is a cosmopolitan city home to several ethnic groups of diverse origins, including the Diakanké, Fulani, Landouma, Soussou, Baga, Nalu and Mikiforè. According to the 2017 census, Boké's population is estimated at 1,190,724 inhabitants, with a density of 38 inhabitants per km²[7].

Fauna and flora: The prefecture of Boké is rich in biodiversity, home to a variety of animal species, such as various insects (locusts, caterpillars, butterflies), reptiles (snakes, lizards) and primates (monkeys, chimpanzees, baboons). In terms of vegetation, the region is mainly covered by wooded savannah [8].

The coastline is home to an area of mangrove swamps, interspersed inland with vast expanses of palm trees. The tropical forest spreads out in narrow strips along river valleys and on the slopes and peaks of mountain ranges, known as gallery forest [9].

Currently, it is essential to implement preventive measures, as nature and vegetation are impacted by bush fires, deforestation, hunting and mining [10].

Production process: During the development and mining phases, minerals are extracted through operations that are generally similar. The mining stages include fundamental operations used to produce the ore, as well as support operations. The stages directly related to mining extraction are called production operations, forming the production operations cycle [11]. The auxiliary stages that support this cycle are referred to as auxiliary action operations.

The production cycle uses unit operations, generally grouped into rock fragmentation and broken material handling operations, which mainly consist of drilling and blasting. Material handling includes loading or excavation and transport (horizontal transport) and sometimes lifting (vertical or inclined transport) [12]. At the Sangarédi mine, transport is carried out horizontally.

Production stages: Drilling, Blasting, Loading, Transport

Although production operations tend to be separate and cyclical, the modern mining industry is moving towards the integration or combination of these functions, while promoting more continuous extraction. For example, in the extraction of coal and other soft rocks, continuous miners simultaneously crush and load the ore, eliminating the need for drilling and blasting.

Drilling and Blasting: At Compagnie des Bauxites de Guinée (CBG), the two parameters of the production cycle—drilling and blasting—are carried out by a subcontractor, NITROKEMINE (NITRO). Under the terms of the contract, NITRO is responsible for ensuring that the rock is adequately fragmented. After blasting, NITRO verifies the success of the operation by ensuring that the fragmentation is correct and that the shots are accurately oriented.

With regard to particle size, any block larger than or equal to 1 m is re-fragmented using a jackhammer. This procedure continues throughout the production chain. Large blocks are sorted and set aside during loading at the face, as well as during stock levelling and loading into wagons.

Ore Loading and Transport: Loading and transport operations are closely linked. The time spent loading represents a significant portion of the total cycle required for a transport truck to complete its journey [13].

Loading involves transporting mined ore using a hydraulic excavator or loader, either directly from the mining face or from a storage area, and placing it into a means of transport. Hydraulic excavators can use two loading methods: normal loading and reverse loading [14]. In reverse loading mode, the excavator is at the same level as the lorries during loading, which increases the time required for this operation, as the excavator has to perform a greater number of movements, as shown in (Figures 2 and 3) relating to reverse loading.

Figure 2: Loading process on the Sangarédi plateau [13].

Figure 2: Loading process on the Bouroré plateau 1 [13]

Transportation : Transportation is one of the most essential stages of mining operations, as all other mining activities are evaluated based on the quality and quantity of the ore extracted, which determine production. After mining, the ore must be transferred to a storage area or crusher to reduce its particle size. Modes of transport include trucks, trains and conveyor belts, among others. At the Sangarédi mine, the extracted ore is loaded onto trucks (dump trucks) which then transport it to a storage area. Figure 4 illustrates the type of trucks used by CBG.

Figure 3: Transport truck at N'dangara Park [13].

II: MATERIALS AND METHODS

II.1. Materials

II.1.1 Bauxite: The history of geological research in the study area is inextricably linked to studies conducted at the national level, particularly in the coastal region of Guinea, of which it is a part. Bauxite is mainly composed of three minerals: gibbsite

($Al_2O_3.3H_2O$), boehmite ($Al_2O_3.H_2O$) and diaspore ($Al_2O_3.H_2O$) [14]. In tropical regions, due to the alternation of two seasons, the diaspore interstices are often replaced by those of boehmite. This is why these tropical bauxites are generally characterised by the presence of two main minerals: gibbsite and boehmite [12].

Small deposits can be found to the west (such as Parawi, Koobi, Bourorè, Wossou), whose frequency decreases as one moves away from the Sangarédi deposit. It should be noted that Sangarédi-type bauxite outcrops are also found throughout the territory, even in North-Cogon, and can sometimes be misleading in geological studies, as in some places their thickness does not exceed 30 cm [11]. Sedimentary lateritic bauxites, which are very rich in aluminium hydroxide (>60%), make Sangarédi the largest and richest bauxite deposit in the world, making it a unique site. There are three genetic types of bauxite within the CBG concession: in-situ or residual lateritic bauxites, sedimentary lateritic bauxites, and chemogenic bauxites (gelified and gelomorphic). The elements that distinguish them visually include facies, texture and structure.

Lateritic bauxites, also known as in-situ or residual bauxites, are formed by the weathering of parent rocks. These include Palaeozoic sedimentary rocks, such as Devonian Faro 1 and Faro 2 Aleuro-Clays, as well as Mesozoic dolerite intrusions (dolerites). In-situ bauxites account for 75% of the total reserves located within the CBG territory. There are several types of facies, including the following: structural bauxite, fragmentary bauxite, brecciated bauxite and skeletal bauxite. Some examples of these facies are illustrated in Figures 5 and 6 below.

Figure 4: Bauxite Structurelle [10].

Figure 5: Skeletal Bauxite [10].

Chemogenic sedimentary bauxites are formed by the recrystallisation of previously established bauxites, derived from the two earlier genetic types (residual or sedimentary from the Sangarédi series), resulting in additional enrichment in aluminium hydroxide. Within the CBG territory, these chemogenic bauxites represent approximately 3% of total reserves. The main characteristic facies of this type include gelified bauxites, gelomorphic bauxites, as well as oolitic and pisolitic bauxites. Figures 7, 8 and 9 illustrate the various facies present in these samples.

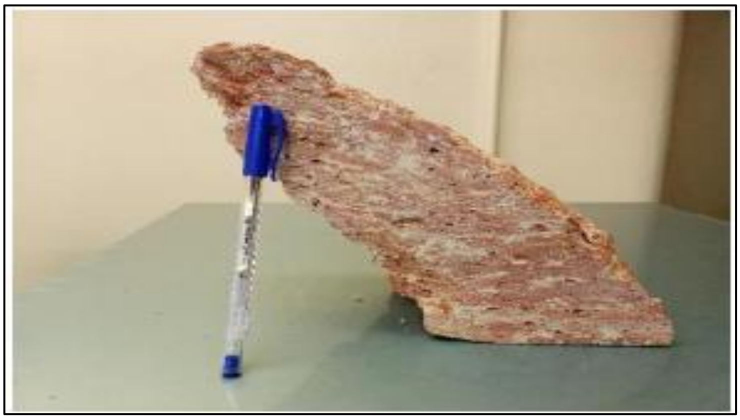

Figure 6: Gelatinised bauxite [12]

Figure 7: Gelomorphic bauxite [12].

II.1.2 Tools Loaders : At the Sangarédi mine, CATERPILLAR 992K and KOMAT'SU KWA 900 loaders are used, which come from the United States and Japan respectively. Although several design options exist, these loaders follow a unique construction pattern. The arm is articulated at the end of the loader bucket, which is controlled by a hydraulic system that allows for digging, filling, lifting and tipping [12].

It has a high forward thrust capacity, which allows it to quickly move and load large quantities of excavated material thanks to its spacious bucket. Its powerful engine and large wheels ensure remarkable stability and versatility in a wide range of applications.

Figure 8: Loader at N'dangara Park [7]

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Excavators are excavation and loading machines widely used in open-pit mines, adapted to various types of terrain. Mechanical excavators, or cable excavators, generally operate on slopes, while hydraulic excavators can operate on slopes, in trenches or in reverse. The power source used can be either diesel or diesel-electric.It should be noted that all movements of these machines are performed using cylinders operated by hydraulic pumps. These pumps have variable flow and pressure regulation. CBG has three hydraulic excavators, two of which are backhoe and one of which is front-end. Figure 10 shows the excavator used at the Sangarédi mine.

Figure 9: Backhoe loader in N'dangara West 3 [13]

II.2 Methods

The objective of this study is to analyze the factors affecting the performance of loading equipment in order to optimize production and reduce operating time. The methodological approach adopted is analytical and is based on the identification and evaluation of key performance indicators (KPIs).

1. Methodological Framework

The study was conducted in four main stages:

1. Review of relevant scientific and technical literature;

2. Collection of operational and production data;

3. Identification and analysis of factors influencing loading equipment productivity;

4. Proposal of improvement measures to optimize equipment performance.

2. Data Sources and Study Period

Operational data were obtained from the Compagnie des Bauxites de Guinée (CBG) and include planned time, availability time, effective working time, downtime, and production records. The analysis focuses primarily on data collected during **July 2023**, complemented by comparative data from other operating periods when necessary.

3. Technical Performance Indicators

Equipment performance was assessed using standard technical indices:

- **Availability coefficient (Kd)**, defined as the ratio of available operating time (Td) to planned time (Tp), which reflects the technical reliability of the equipment.

- **Utilisation coefficient (Ku)**, calculated as the ratio of effective working time to planned time, accounting for operational organization and working conditions.

- **Time-loss coefficient (Δpt)**, determined as the difference between availability and utilisation coefficients (Δpt = Kd − Ku), which quantifies operational inefficiencies.

These indicators were calculated for each loader, with the CAT 992 (equipment 062) at the Bourorè 2 site used as a reference case. Results for all machines are presented in the Results and Discussion section.

4. Production Parameters and Operating Efficiency

The practical production efficiency of the excavators was evaluated per shift using the following relationship:

$$Q_{ex/p} = \frac{3600 \times E \times Ku \times Kr \times Tp}{Tc \times Kf}$$

where ***E*** is the bucket capacity, ***Ku*** the utilisation coefficient, ***Kr*** the bucket filling factor, ***Tp*** the shift duration, ***Tc*** the cycle time, and ***Kf*** the rock expansion coefficient. A bauxite density of **2 t/m³** was assumed for production calculations. Detailed results are provided in the Results and Discussion section.

5. Factors Affecting Loading Performance

Factors influencing loading performance were grouped into two main categories:

- **Technical factors**, including equipment breakdowns, maintenance delays, tyre wear, mechanical reliability, and operator fatigue.

- **Organisational factors**, such as loader cycle time, shift delays, waiting times at loading faces, haulage distances, equipment and operator availability, site accessibility, mine layout, road conditions, and truck availability.

This structured approach enabled a comprehensive assessment of both technical and organisational constraints affecting loading equipment performance.

III- RESULTS AND DISCUSSIONS

This section presents and analyzes the key performance indicators used to assess the operational efficiency of loading equipment at the Sangarédi mine. The results obtained are compared with the production objectives defined by CBG and discussed in light of existing literature.

III.1 Evaluation of performance indicators

III.1.1 Availability coefficient

The availability coefficients of the loading equipment The time loss coefficients, calculated as the difference between the availability and utilisation coefficients, are shown in Figure 11. The results show that, under normal operating conditions, most machines exhibit satisfactory availability, with values ranging between 50% and 90%. During the internship period, the DEMAG H-95 operating at the Débélé mine recorded an availability coefficient of 67%, indicating acceptable technical reliability relative to its planned operating time [15]. Similarly, loader (062) showed an availability coefficient of 71.55%, which can be explained by its limited downtime of 38.78 hours recorded in January.

At the scale of the Sangarédi mine, the average availability coefficient of the seven loading machines reached 91.77% [16], suggesting that mechanical reliability is generally not the primary constraint on production. These results are consistent with findings reported in previous studies, which indicate that availability rates above 85% are typical for well-maintained mining equipment operatng under stable conditions [12].

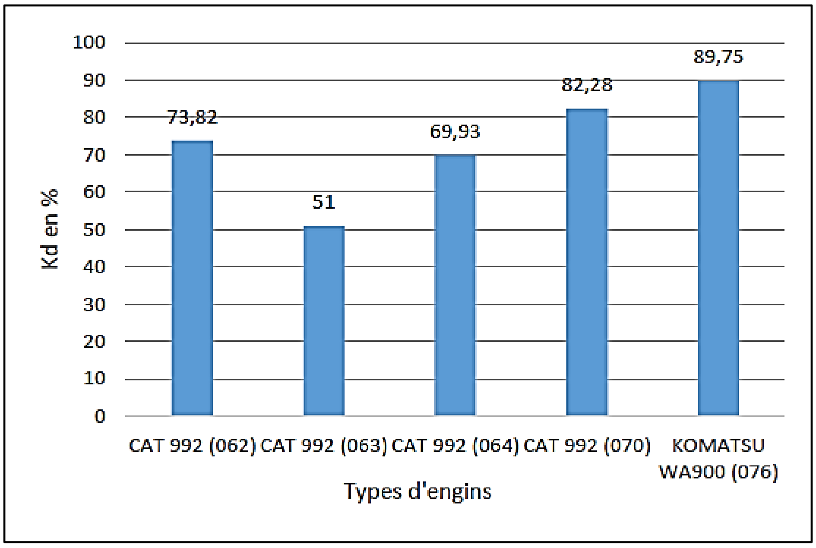

Figure 10: Graphical representation of availability coefficients

III.1.2 Coefficient usage

The utilisation coefficients, the time loss coefficients, calculated as the difference between the availability and utilisation coefficients, are shown in Figure 12, reveal greater variability among the machines. Loader (076) recorded the highest utilisation rate (82.76%), indicating efficient operational use, whereas loader (063) showed a utilisation coefficient below 50%, reflecting underutilisation despite adequate availability. Excavator (062) exhibited a moderate utilisation coefficient of 56.99%, which is low compared to its planned operating time of 744 hours.

Overall, the average utilisation coefficient for the loading equipment at the Sangarédi mine is 66.73% [14]. This result highlights a significant gap between equipment availability (approximately 91%) and actual utilisation (66%), suggesting that organisational and operational constraints play a major role in limiting productivity. Similar discrepancies between availability and utilisation have been reported in the literature and are often attributed to inefficiencies in work organization, haulage coordination, and shift management [18].

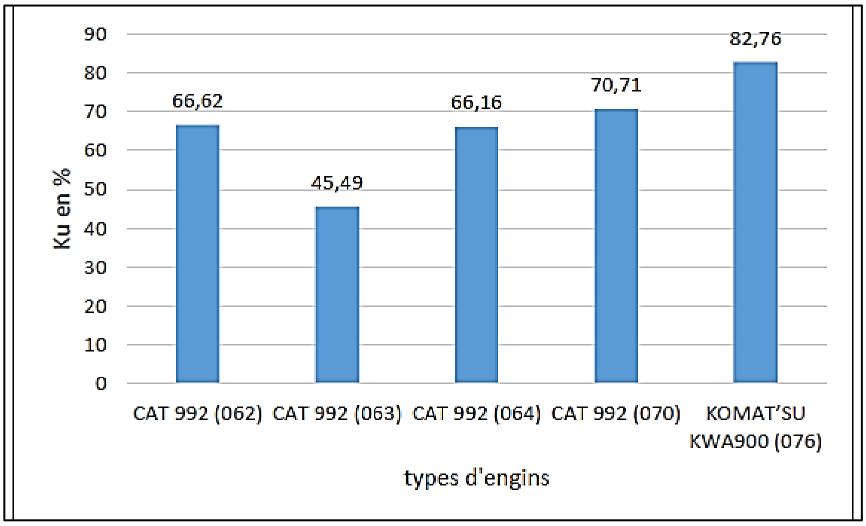

Figure 12: Graphical representation of utilisation coefficients

III.1.3 Time loss coefficient

The time loss coefficients, calculated as the difference between the availability and utilisation coefficients, in Figure 13.The highest time losses were recorded for equipment (070) during July 2023 [10], indicating significant operational inefficiencies. In contrast, the DEMAG H-95 showed a relatively low time-loss coefficient of 15%, demonstrating better alignment between availability and effective working time [1].

When compared with earlier studies, notably that of Camara and Keita (2012) [18], who reported a time-loss coefficient of 30.82% in January 2012, the current results suggest an overall improvement in operational control at the Sangarédi mine. However, time losses remain higher than those reported for certain loaders, such as the Komatsu WA900 (6.99%), indicating further potential for optimisation.

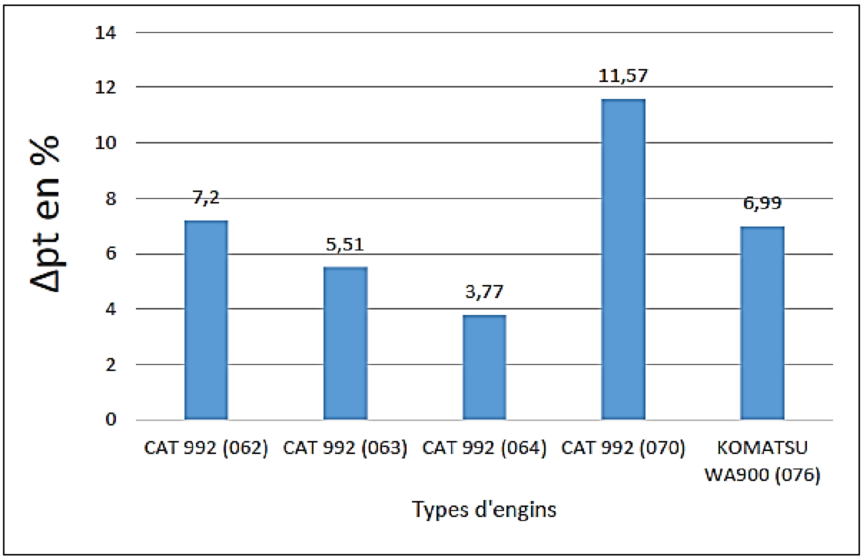

Figure 11: Représentation graphique des pertes

III.1.4 Production parameters

The actual productivity results for the excavators are shown in Figure 14. Given that eight excavators with similar bucket capacities are currently in use at the mine, the total practical annual excavation capacity has been estimated as follows:

$$Q_{exc/year} = 994{,}680 \times 8 = 7{,}957{,}440 \text{ m}^3/\text{year}$$

Considering a bauxite density of 2 t/m³, this corresponds to a practical annual production of:

$$Q_{exc/year} = 15{,}914{,}880 \text{ t/year}$$

Despite this theoretical capacity, production performance between January and July 2023 remained below expectations. While CBG planned to produce 9,862,853 tonnes of bauxite during this period, actual production reached only 9,375,777 tonnes, resulting in a shortfall of 487,076 tonnes. This gap highlights the impact of suboptimal equipment utilisation and time losses, rather than limitations in equipment capacity.

A similar situation is observed at the Chouf-Amar quarry, where the theoretical annual production capacity is estimated at 3,876,000 tonnes. However, calculations show an actual production of approximately 3,577,079 tonnes per year using two loaders with 8 m³ bucket capacity [19]. This further confirms that organisational and operational inefficiencies significantly affect production outcomes.

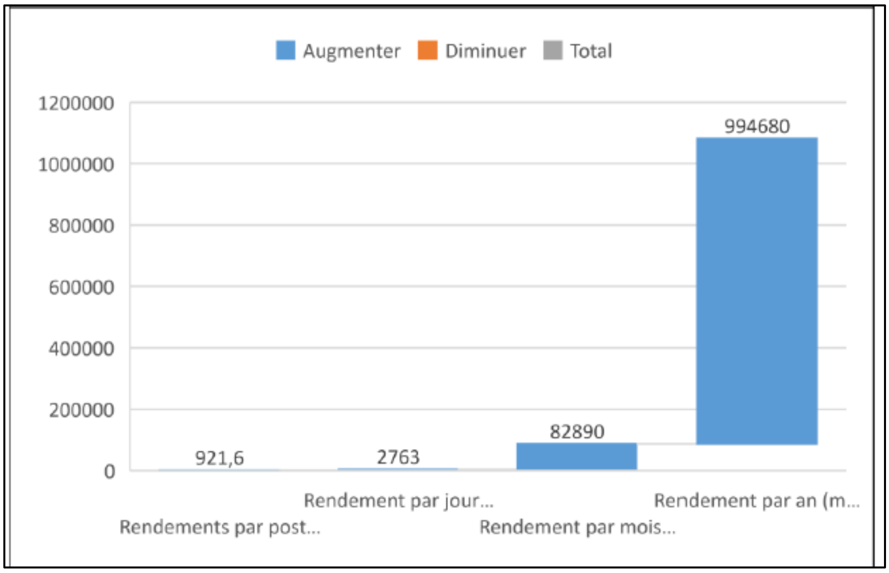

Figure 12: Graphical representation of loader performance by period

The results indicate that improving production performance at the Sangarédi mine requires not only maintaining high equipment availability but also enhancing utilisation rates. Priority actions should focus on reducing organisational delays, improving coordination between loading and haulage operations, optimizing shift management, and strengthening preventive maintenance planning. By addressing these factors, CBG could significantly reduce time losses and better align actual production with planned objectives.

DISCUSSIONS

It should be noted that, under normal operating conditions, most of the loading equipment is generally available, with availability coefficients ranging from 50% to 90%. During the internship period, the DEMAG H-95 operating at the Débélé mine recorded an availability coefficient of 67%, which can be attributed to its satisfactory operational condition relative to its planned operating time [15]. Similarly, equipment (062) exhibited an availability coefficient of 71.55%, reflecting its low downtime of 38.78 hours in January. In addition, the average availability coefficient of the seven loading machines operating at the Sangarédi mine was estimated at 91.77% [16].

A comparison of utilisation coefficients indicates that equipment (076) was the most intensively used, with the highest utilisation rate of 82.76%, whereas equipment (063) showed the lowest utilisation, with a rate below 50%. Excavator (062) recorded a utilisation coefficient of 56.99%, which explains its relatively low level of use compared to its planned operating time of 744 hours. Overall, the loading equipment at the Sangarédi mine operates within acceptable utilisation levels, with an average utilisation coefficient of 66.73% [14]. This analysis shows that, at the Sangarédi mine, loading equipment is available approximately 91% of the time but is effectively utilised only about 66% of that available time. The DEMAG H-95 exhibits a utilisation coefficient of 52%, which is comparable to the lowest utilisation rate observed for the CBG loader (063).

According to the operational data, the greatest time losses were recorded for equipment (070) during July 2023 [10]. In contrast, the DEMAG H-95, with a relatively low time-loss coefficient of 15%, stands out as the machine that effectively operated for a significant portion of its available time compared to the other units [1]. Furthermore, the study by Camara and Keita (2012) [18] reported a time-loss coefficient of 30.82% in January 2012, which is considerably higher than those recorded for the Komatsu WA900 loader (6.99%) and the DEMAG H-95 (15%).

Given that eight excavators are currently operating at the Sangarédi mine and that they have similar bucket capacities, their total practical annual production can be estimated as follows:

$$Q_{ex}c/year = 994{,}680 \times 8 = 7{,}957{,}440 \text{ m}^3/\text{year}.$$

Considering that the density of the bauxite mined by CBG is approximately 2 t/m³, the practical annual production of the loading equipment operating at the mining faces becomes:

$$Q_{ex}c/year = 7{,}957{,}440\ m^3/year \times 2\ t/m^3 = 15{,}914{,}880\ t/year.$$

From January to July 2023, CBG planned a production of 9,862,853 tonnes of bauxite but achieved only 9,375,777 tonnes, resulting in a production shortfall of 487,076 tonnes.

Finally, the annual production capacity of the Chouf-Amar quarry is estimated at 3,876,000 tonnes. However, calculations indicate an actual production of approximately 3,577,079.16 tonnes per year using two loaders with a bucket capacity of 8 m³ [19].

CONCLUSION

The objective of this study, which focused on analysing the factors influencing the performance of loading equipment at the Sangarédi mine (CBG), was to optimise the efficiency of these machines in order to improve productivity.

The first step in this study involved identifying the main performance indicators used at the CBG mine, as well as analysing and interpreting them to detect any shortcomings that needed to be corrected.

The identification of these performance indicators highlighted the associated coefficients and calculation methods. The analysis consisted of comparing, for each indicator, the planned targets with the results obtained during the first half of 2023.

The tables produced made it possible to observe and identify the loaders, ranking them from the most efficient to the least efficient.

To achieve a half-yearly target of 9,862,853 tonnes of bauxite with 14 excavators, we produced 9,283,680 tonnes of bauxite using only 8 front-line machines.

Machine availability was relatively satisfactory, with a rate varying between 50% and 90%. However, the utilisation of the loader (063) was insufficient, at only 45.49%.

Analysis of the results highlighted several causes of the weaknesses observed, such as the age of the machines, time management, the lack of maintenance interventions in certain areas and the lack of availability of operators, among others.

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CONFLICTS OF INTEREST

This article presents no conflict of interest, and the authors favor the publication of their works in this journal.

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