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Analysis of heavy mobile equipment maintenance performance in an Open-Pit Gold Mine

Drissa Mohamed Malo *

Department of Mechanical Engineering, Université NAZI BONI, 01 BP 1091 Bobo-Dioulasso, Burkina Faso.

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Abstract

This study analyzed the maintenance performance of heavy mobile equipment at a gold mine in Burkina Faso over a full year, from June 2024 to May 2025. The research tracked key performance indicators month by month for five equipment types: haul trucks, excavators, wheel loaders, graders, and dozers. The data came directly from the mine's maintenance records. We measured equipment availability, failure frequency, repair times, costs, and the balance between planned and emergency work. Results show a clear seasonal pattern. During the rainy season, equipment broke down more often, and repairs took longer. This caused a drop in equipment availability and higher operating costs. Haul trucks performed the worst, while graders and dozers were the most reliable. The study found that maintenance strategy shifts from planned preventive work in the dry season to reactive breakdown repairs in the rainy season. The study identifies specific failure causes like tire damage and hydraulic leaks that are most common during the rains. Based on the findings, we recommend concrete actions including a pre-rainy season maintenance program, better spare parts planning, and targeted technician training. These steps can help mines in similar climates improve equipment reliability and reduce costs.

Keywords: Heavy Mobile Equipment; Maintenance Management; Key Performance Indicators; Open-Pit Mining; Burkina Faso; Seasonal Variations

1. Introduction

Mining is a vital economic activity in Burkina Faso [1–6]. The country is now one of Africa's leading gold producers [7, 8]. This production relies heavily on open-pit mining methods. In these operations, heavy mobile equipment such as haul trucks, excavators, and loaders forms the backbone of material movement [9–11]. The continuous and reliable operation of this equipment directly determines whether production targets are met, costs are controlled, and safety is maintained [12–16].

Maintaining this equipment in remote mining locations presents distinct difficulties [17–21]. Sites are often far from major cities and suppliers. The local climate features a long, harsh dry season with high dust levels, followed by an intense rainy season that turns ground conditions to mud. These environmental factors cause rapid wear on machine components like tires, tracks, and hydraulic systems. Getting spare parts and specialized tools to site can be slow and expensive [22–29]. These conditions make a systematic approach to equipment maintenance not just beneficial, but essential for survival of the operation.

A systematic approach requires measurement. In maintenance management, Key Performance Indicators are the standard tools for this measurement [30–34]. KPIs turn operational data into clear metrics that show how well maintenance activities are performing. Common examples include the percentage of time equipment is available to

* Corresponding author: Drissa Mohamed Malo

work, the average time between failures, and the average time it takes to complete a repair. By tracking these numbers over time, managers can see if performance is improving or declining, identify the root causes of problems, and make informed decisions.

While the use of KPIs in mining maintenance is a well-established practice globally, there is a lack of detailed, medium-term studies from West African open-pit mines [35–37]. Many existing reports are based on short data collection periods or focus on processing plants rather than mobile fleets. Furthermore, there is limited published analysis on how the pronounced seasonal weather patterns in the Sahel region specifically impact equipment reliability and maintenance efficiency over a full annual cycle.

This study aims to address that gap. It presents a detailed, one-year analysis of maintenance performance for a fleet of heavy mobile equipment at an active gold mine in Burkina Faso. The objective is to track a core set of KPIs month-by-month across different equipment types. The study seeks to answer several practical questions: How does equipment reliability change between the dry and rainy seasons? What are the most common and costly types of equipment failure? How effective are current preventive maintenance practices? And what specific actions can management take to improve equipment availability and reduce operating costs?

The findings from this longitudinal analysis are intended to provide mine managers, maintenance planners, and engineers with evidence-based insights. The goal is to support better planning, smarter resource allocation, and ultimately, more productive and cost-effective mining operations in Burkina Faso and similar regions.

2. Methods

2.1. Site and Equipment Description

This study was conducted at a large-scale open-pit gold mine located in Burkina Faso. It operates under the mining laws of Burkina Faso and holds all necessary environmental and social permits [38–40]. The climate follows a typical Sudano-Sahelian pattern [41, 42]. The year is divided into two main seasons. A long dry season lasts from approximately October to May. During this period, daytime temperatures are high, and dust levels are significant. A distinct rainy season occurs from June to September. Heavy rainfall during these months creates muddy conditions across the mining site, affecting ground stability and machine traction.

The mining method is conventional open-pit [43, 44]. The operation involves drilling, blasting, loading, and hauling. The maintenance of heavy mobile equipment is, therefore a critical daily activity. The mine's maintenance department is organized into dedicated teams. These include a mechanical team for engine and chassis repairs, an electrical team for machine controls and wiring, and a specialized tire maintenance team. Staff work on a rotational schedule of 14 consecutive working days followed by 14 days off. This schedule accommodates the remote location of the site.

The study monitored the mine's primary production fleet from June 2024 to May 2025. The specific machines and their core functions are listed below in Table 1.

Table 1 Heavy Mining Equipment List

Equipment Type	Model	Quantity	Primary Function	Average Annual Operating Hours (per unit)
Haul Trucks	Caterpillar 777F	14	Transport of ore from the pit to the ROM pad or waste dumps.	5200
Hydraulic Excavators	Komatsu PC1250	3	Loading of fragmented rock into haul trucks	5800
Wheel Loaders	Caterpillar 993K	1	ROM bin feeding and material rehandling	4100
Graders	Caterpillar 14M	2	Road maintenance	3900
Dozers	Caterpillar D9R	2	Pit floor dozing and ROM pad clean up	3600

All equipment data was sourced from the mine's centralized Computerized Maintenance Management System [45, 46]. This system records every work order, including the machine identification, type of failure, parts used, labor hours, and technician comments. This digital record-keeping provided the complete and consistent dataset required for the one-year analysis.

2.2. Data collection

The purpose of this study was to measure and analyze maintenance performance over time. To achieve this, we collected, organized, and calculated data for one full year. This section explains the step-by-step process we followed. We collected data from June 2024 to May 2025. All information came from the mine's official records. The primary source was the mine's Computerized Maintenance Management System (CMMS). This digital system logs every maintenance action. We also used equipment hour meter readings, fuel and lubricant consumption reports. This approach ensured the data was reliable and consistent.

2.3. Key Performance Indicators (KPIs) Selection

We selected seven standard maintenance KPIs for this analysis [47, 48]. These indicators were chosen because they are widely recognized in the mining industry and provide a clear picture of different aspects of maintenance performance. Table 2 lists each KPI, its formula, and what it measures.

Table 2 Key Performance Indicators and Their Calculation

KPI	Formula	What It Measures
Maintenance Effectiveness (ME)	(Operating Time / (Operating Time + Downtime)) x 100%	The percentage of time equipment was available to work versus total scheduled time.
Mean Time Between Failures (MTBF)	Total Operating Time / Number of Failures	The average operating hours between one breakdown and the next.
Mean Time to Repair (MTTR)	Total Downtime / Number of Failures	The average hours required to repair a piece of equipment after a failure.
Preventive Inspection Effectiveness (PIE)	(Preventive Repair Hours / Preventive Inspection Hours) x 100%	How many inspection hours actually led to repair work, indicating inspection quality.
Ratio of Preventive to Breakdown Maintenance (RPBM)	Total Preventive Hours / Total Breakdown Repair Hours	The balance between planned preventive work and unplanned reactive work.
Maintenance Backlog	Total Man-Hours of All Open Work Orders	The total amount of planned or overdue work not yet completed.
Cost per Operating Hour (CPOH)	(Parts Cost + Labor Cost + Lubricant Cost) / Total Operating Hours	The total maintenance cost for each hour the equipment was running.

2.4. Data Processing and Analysis

Data processing followed a consistent monthly routine [49]:

- **Extraction**: At the end of each month, raw data was exported from the CMMS and other digital systems.
- **Categorization**: Each work order was categorized by equipment type, failure type, and whether it was a preventive or breakdown task.
- **Calculation**: The monthly data for each equipment type was entered into the KPI formulas. This produced a monthly value for each KPI.
- **Aggregation**: Monthly results were then combined into quarterly and annual averages to observe larger trends.

To understand seasonal impacts, we grouped the months into four quarters that align with the local climate:

- Q1 (June 2024 – August 2024): Transition into the rainy season.
- Q2 (September 2024 – November 2024): Early dry season, conditions improving.

- Q3 (December 2024 – February 2025): Late dry season, hot and dusty.
- Q4 (March 2025 – May 2025): Transition into the rainy season.

2.5. Failure Analysis

For the most frequent failures, we performed a root cause analysis. This involved reviewing the technician notes and parts used for each repeated failure. The goal was to determine if failures were due to part quality, operating conditions, or maintenance procedures.

2.6. Limitations

Two main limitations existed. First, data quality depended on the accuracy of the technicians' entries into the CMMS. Second, external factors like global supply chain delays affected parts availability, but their specific daily impact was difficult to isolate numerically. We accounted for these limitations by cross-checking major downtime events with workshop manager logs.

3. Results

The analysis of maintenance data from June 2024 to May 2025 shows clear patterns in equipment performance. Results are presented first for the overall fleet across the four seasons, then for each equipment type for the full year.

3.1. Quarterly Performance for the Mobile Fleet

Equipment performance was worst during the rainy season (Quarter 1) and best during the middle of the dry season (Quarter 3), as shown in Table 3. Equipment was available to work only 77.5% of the time in the rainy season (Q1), compared to 88.9% in the dry season (Q3). Machines broke down every 88 hours on average in Q1. This improved to breaking down every 162 hours in Q3. The average repair took 9.5 hours in Q1, but only 5.6 hours in Q3. In Q1, only 1.6 hours were spent on preventive work for every 1 hour spent on breakdown repairs. This improved to a ratio of 3.6 in Q3. The cost to maintain each hour of operation was highest in Q1 at $175.40. The backlog of unfinished maintenance jobs was highest in Q1 at 68 hours.

Table 3 Key Performance Indicators and Their Calculation

Quarter	ME (%)	MTBF (hrs)	MTTR (hrs)	PIE (%)	RPBM	Backlog (hrs)	CPOH (USD)
Q1 (Jun–Aug '24)	77.5	88.1	9.5	10.1	1.6	68	175.4
Q2 (Sep–Nov '24)	83.8	126.3	6.8	15.8	2.5	40	145.2
Q3 (Dec '24–Feb '25)	88.9	162.5	5.6	20.1	3.6	22	127.5
Q4 (Mar–May '25)	86.5	143.2	6.2	17.2	2.8	31	137.9

3.2. Annual Performance by Equipment Type

Table 4 Annual KPI Summary by Equipment Type (Jun '24 – May '25)

Equipment	ME (%)	MTBF (hrs)	MTTR (hrs)	PIE (%)	RPBM	Avg. Backlog (hrs)	CPOH (USD)
Haul Trucks	79.8	108.5	7.8	13.2	2	52	163.8
Excavators	88.5	158.9	6	19	3.3	24	133.5
Wheel Loaders	83.2	130.4	6.9	14.9	2.3	36	147.1
Graders	90.1	205.7	4.8	22.5	4.1	15	122.3
Dozers	91	212.3	4.6	22.8	4.3	13	120.1
Fleet Average	86.5	163.2	6	18.5	3.2	28	137.4

Over the full year, haul trucks had the poorest performance and highest cost. Graders and dozers were the most reliable, as presented in Table 4.

3.3. Monthly Trends

Figure 1 and Figure 2 show how reliability and repair times changed month by month for the best and worst performing equipment.

Figure 1 shows a clear pattern for all equipment types: breakdowns happened most often during the rainy season (June to August 2024) and least often during the middle of the dry season (December 2024 to February 2025). Haul trucks broke down the most frequently of all equipment, especially in August 2024 when they failed every 75 hours. Excavators and wheel loaders followed a similar pattern but broke down less often than haul trucks. Graders and dozers were the most reliable. They broke down much less frequently than the other equipment throughout the entire year, maintaining over 190 hours between failures even during the worst months. After the rainy season ended, all equipment types showed improved reliability, with haul trucks reaching their best performance in January 2025 (140 hours between failures). This shows that dry operating conditions significantly reduce breakdown frequency across the entire fleet.

Figure 2 shows that repairs took the longest during the rainy season (June to August 2024). During this period, repairs for haul trucks, excavators, and wheel loaders all took over 8.5 hours on average. Haul truck repairs were consistently the slowest, taking up to 10.2 hours in July.

Repair times improved steadily as the dry season began. All equipment types showed their fastest repair times during the peak of the dry season (December 2024 to February 2025), with haul trucks dropping to 6.5 hours per repair in January. Graders and dozers were consistently repaired the fastest throughout the year, taking around 4-6 hours per repair. Their repair times were less affected by seasonal changes compared to the other equipment types.

The pattern shows that muddy conditions and parts delays during the rainy season significantly slow down maintenance work, while dry conditions allow for more efficient repairs across all equipment types.

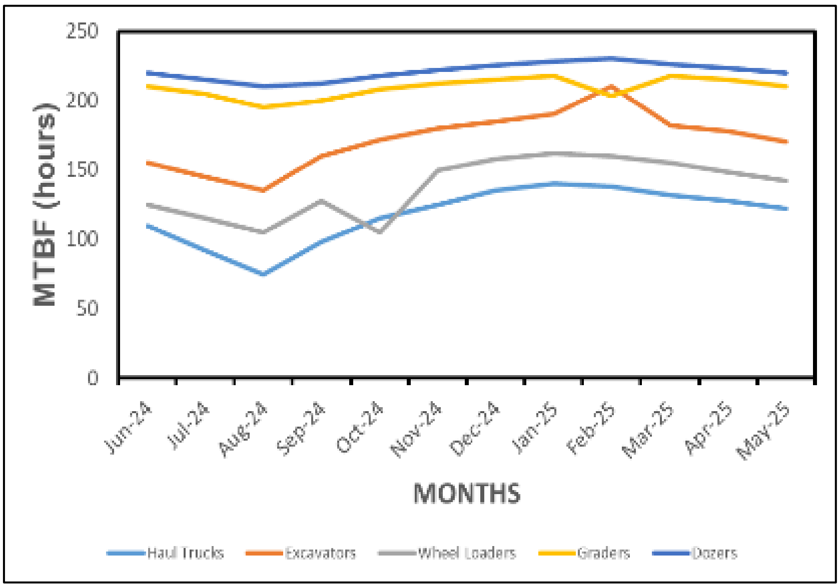

Figure 1 Monthly MTBF (Mean Time Between Failures) in Hours

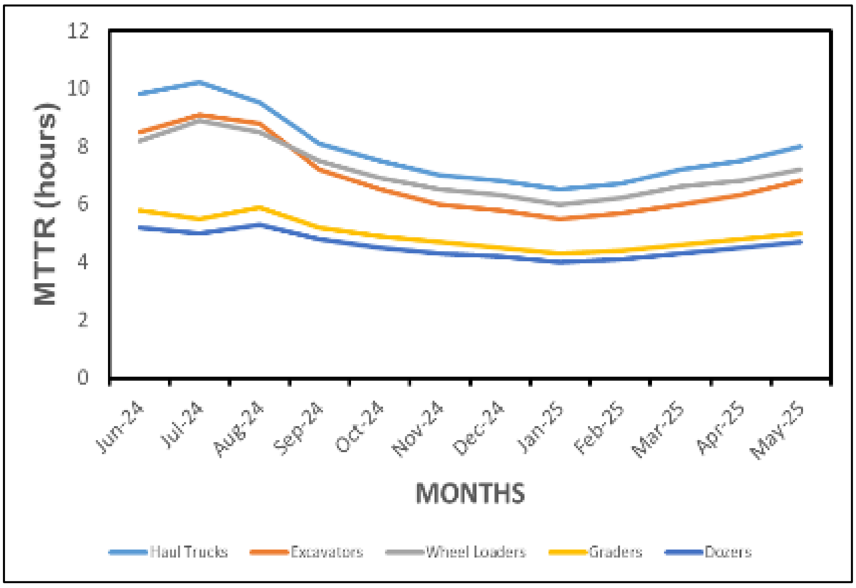

Figure 2 Monthly MTTF (Mean Time Between Failures) in Hours

3.4. Common Causes of Failure

A review of all repair records identified the parts and systems that failed most often (Table 5).

Table 5 Most Frequent Failure Modes (Jun '24 – May '25)

Equipment	Most Common Failure	Number of occurences	Avg. Repair Time (hrs)	Main Reason
Haul Trucks	Tire Damage	135	6.8	Wet, muddy pit floor (Q1) and sharp rocks
	Brake Problems	91	9.1	Dust clogging and extreme heat from stopping heavy loads
Excavators	Hydraulic Hose Burst	81	8.3	Hoses rubbing against surfaces or failing under high pressure
	Track Pad Wear/Break	60	7.5	Metal parts grinding against abrasive ground material
Wheel Loaders	Bucket & Linkage Wear	98	6.2	Constant loading of abrasive rock
	Steering Axle Issues	45	8.5	Stress from heavy, twisting loads
Graders	Moldboard & Blade Wear	28	5.5	Scraping against gravel on roads daily
	Hydraulic Cylinder Leak	20	4.2	Seals wearing out over time
Dozers	Track Roller Wear	52	6.4	Metal rollers constantly moving over rough ground
	Ripper Shank Break	18	5	Snapping when hitting very hard rock

4. Discussion

The results from the 12-month study show two clear and connected patterns. First, equipment breaks down more often during the rainy season [50–52]. Second, repairs take longer during that same period. These two problems combine to cause a significant drop in equipment availability when the mine needs to maintain production.

The rainy season is the main cause of these problems. Muddy conditions damage haul truck tires quickly. Wet weather also leads to more electrical faults in all machines. These specific failures, shown in Table 5, happen more often in the rainy months. The data in Figure 1 confirms this, showing that the time between failures (MTBF) drops sharply for all equipment from June to August.

When equipment breaks down more often, the maintenance team has more repairs to do. At the same time, repairs become harder to complete. Figure 2 shows that the average time to complete a repair (MTTR) is highest during the rainy season [53]. There are practical reasons for this. Muddy access roads can delay mechanics from reaching a broken-down machine. Waiting for special parts can take longer if delivery trucks are delayed by bad weather.

The data also shows that the type of maintenance changes with the seasons. During the dry season, the team does more planned preventive work. The Ratio of Preventive to Breakdown Maintenance (RPBM) in Table 3 is high in Q3 (3.6). This means for every hour spent fixing breakdowns, over three hours are spent on preventive checks. This strategy works. Equipment is more reliable and cheaper to run in the dry season.

In the rainy season, this balance flips. The RPBM drops to 1.6 in Q1. The team is forced to spend most of its time reacting to emergencies, not preventing them. This reactive approach is less effective and more expensive, as shown by the high Cost per Operating Hour (CPOH) during this period.

The comparison between equipment types is also important. Haul trucks are the biggest concern. They have the lowest reliability (MTBF) and the highest repair times (MTTR) and costs (CPOH). Improving their performance would have the largest impact on the mine's overall productivity. In contrast, graders and dozers perform well. Their simpler design and different work cycles make them less vulnerable to the conditions that cause the most problems for haul trucks and excavators.

In summary, the rainy season creates a cycle of more breakdowns and slower repairs [53]. This forces the maintenance strategy to shift from prevention to reaction, which increases costs and reduces equipment availability. Breaking this cycle requires targeted actions before the rains begin.

5. Conclusions

This study tracked the maintenance performance of heavy equipment at a gold mine in Burkina Faso for one full year. The data shows a direct link between seasonal weather and equipment reliability. Performance is worst during the rainy season and best during the dry season. The main finding is that the rainy season creates two simultaneous problems for maintenance. First, it causes equipment to break down more often, especially haul trucks. Second, it makes every repair take longer to complete. These two factors together significantly reduce the amount of time equipment is available for production. This forces the maintenance team to spend most of their time on emergency breakdown repairs instead of planned preventive work.

While all equipment is affected, haul trucks are the most critical issue. They have the highest failure rate, the longest repair times, and the greatest cost impact. Improving their performance is the single most important step for increasing overall mine productivity.

The results point to practical solutions. The problems of the rainy season are predictable. Therefore, the solution is to prepare for them before they happen. Actions must focus on the dry season window to get ready for the rains. This includes changing maintenance schedules, ordering specific spare parts in advance, and training technicians for the most common rainy-season failures.

In summary, equipment maintenance in this environment is a seasonal challenge. By using data to anticipate these seasonal changes, mine managers can move from a reactive to a proactive strategy. This shift is necessary to improve equipment availability, control costs, and support steady production throughout the year.

Abbreviations

The following abbreviations are used in this manuscript:

KPI	Key Performance Indicator
ME	Maintenance Effectiveness
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
PIE	Preventive Inspection Effectiveness
RPBM	Ratio of Preventive to Breakdown Maintenance
CPOH	Cost per Operating Hour
CMMS	Computerized Maintenance Management System
ROM	Run-of-Mine
Q1	Quarter 1 (June-August 2024)
Q2	Quarter 2 (September-November 2024)
Q3	Quarter 3 (December 2024-February 2025)
Q4	Quarter 4 (March-May 2025)
HME	Heavy Mobile Equipment
USD	United States Dollar

Compliance with ethical standards

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Disclosure of conflict of interest

The author has no conflicts of interest to declare that are relevant to the content of this article.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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