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Research Article

Supervisor-Field Engineering Approach (S-FEA) of Determining Tyre Failures in the Haul Trucks at Newmont Ahafo Mine

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Abstract

Surface mining operations depend critically on the durability and performance of haul truck tyres, as achieving optimal operational hours directly influences cost-effectiveness and productivity. This study delves into the causes of premature tyre failures, which prevent mining companies from reaching their operational targets. Among the most frequent types of tyre damage are bead damage, separation, punctures, heat separation, impacts, liner, tube, or rust band failures, radial cracks, and failures due to repairs. Additional issues include seized brakes, shoulder and sidewall cuts, tread chunking, and tread cuts, as well as wear from normal operations. To systematically identify and analyse these failures, the study employed the Supervisor-Field Engineering Approach (S-FEA) during the period from January 2020 to December 2020. The findings indicate that the predominant causes of significant tyre failures are multifaceted, including poor underfoot conditions, presence of water, operator negligence, and incorrect tyre inflation. Other critical factors contributing to tyre deterioration are excessive heat generation, and mechanical stress such as spinning, skidding, or sliding. Additionally, external factors such as rocks becoming lodged between dual wheels, underinflation, and overloading were identified as contributing to tyre failures. The study strongly recommends that mining operations adhere to the specified Ton Mile Per Hour (TMPH) ratings, which are designed to optimize tyre performance by matching tyre capabilities with the operational demands. By adhering to these guidelines, mines can enhance tyre longevity, reduce downtime due to tyre failures, and ultimately achieve a more efficient and cost-effective mining operation. This approach not only addresses immediate operational challenges but also contributes to sustainable mining practices by reducing waste and increasing the reuse of resources.

Keywords

Haul Truck Tyre Life, Supervisor-Field Engineering Approach (S-FEA), Sidewall Cut, Shoulder Cut, Tread Chunking

1. Introduction

Mining industries are compelled to be more efficient and effective as the operation costs keep increasing in the business space. Over the decades, most mining companies have implemented various maintenance strategies and interventions to minimise the operation cost as much as possible. Subsequently, ensuring effective machine utilisation is vital to the overall economic performance of the company. Putting in place proper maintenance practices plays an essential role in

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machine capability. Hence, possibilities must be continually pursued to increase the equipment's operational life to enhance equipment reliability, minimise maintenance costs, and increase productivity. Haul Trucks are indispensable equipment in the hauling operations of the mine. These haul trucks run on tyres, the cost of which contributes massively to the operational cost. Morad *et al.* [1] assert that equipment used in load and haul operations are treasured assets in open-pit-mine, and purchasing and maintaining this equipment is capital intensive as much as their maintenance. According to Yadav *et al.* [2], haul trucks are off-road- very expensive equipment and regular tracking of the equipment’s performance is essential for the mining industry. In addition, they also proved the necessity of the mining companies to have a well-structured system to review performance. Over the years, tyres on haul trucks have not been given the same maintenance recognition and care given to other components such as engines or gearboxes. Newmont Ahafo Mine (NAM), an open-pit mine around Kenyase in the Ahafo Region of Ghana, aims to increase profit by minimising its operational costs as much as possible. However, the feasibility of this aim is largely influenced by the operational life of the haul trucks’ tyres. According to the findings of Galatia, [3], Cutler’s assertion that most tyre suppliers have had about 30% less supply in the market for the past few years still holds. This tyre shortage has caused a high hike in the prices of tyres by more than 400% over the decade. This had a detrimental impact on large mines such as NAM. The mine currently owns thirty-six (36) CAT 785C haul trucks, each running on six tyres. This means the mine operation has exactly 216 tyres working at any point in time. Since its inception, Ahafo South Mine has made many interventions to improve the tyre’s operational life to 7000 hours, which is their target but has not succeeded. It is noteworthy that a range of studies have explored the factors contributing to tyre failures in haul trucks. Lipsett and Anzabi [4] and Knights and Boerner [5] highlight the impact of external factors such as road conditions, ambient temperature, and specific haulage routes. Nyaaba *et al.* [6] delves into the role of tyre compounds and their microstructural in-homogeneities in predicting fatigue life, while Anzabi *et al.* [7] focus on the potential of new condition monitoring methods, including thermal imaging and on-board sensors, to detect faults. These studies collectively underscore the complex interplay of internal and external factors in determining tyre failures in haul trucks which cannot be undermined. Therefore, this study is a step toward investigating the causes of premature tyre failures and then reviewing the maintenance practices adopted by the mine to make appropriate recommendations to the management of Newmont Ghana Gold Limited - Ahafo Mine. To this end, the Supervisor-Field Engineering Approach (S-FEA) was adopted, with the help of the mining supervisor, which sought to employ field observations on:

1) the tyre usage.
2) conditions under which tyre was used,
3) attitude and/or skill of user; and
4) tyre care upon usage.

This way, the causes of premature tyre failures would be unearthed, and recommendations proposed.

2. Methods and Materials

2.1. Materials

The research focuses on the load and haul operational unit of Newmont Ghana Gold Limited – Ahafo South Mine, where loading and hauling is done with haul trucks. The main objective of the field study was to identify the causes of the premature failure of the CAT785C Haul Trucks Tyres at Ahafo South Mine for 10 years (2010 to 2020). The study was conducted pragmatically using both qualitative and quantitative approaches. Using the data obtained from performance reports, participant observation, subject matter expert views (key informants) and Vehicle Information Management System (VIMS), a qualitative analysis was done using the inductive process of building from the data to broaden themes and then generalised model or theory. Quantitative data was analysed using IBM SPSS through descriptive statistics, using graphs and tables to present the data.

2.2. Methods

The authors promulgated the Supervisor-Field Engineering Approach (S-FEA) to assess the field conditions in which the tyres ply. This approach uses the field supervisor's deliberate involvement to inspect working areas such as haul road, pit floor conditions, and operator skill and attitude towards duty of care. The steps involved in the S-FEA technique (see Figure 1) include:

1) Setting an objective or question that will lead to a complete assessment of field conditions in mining operations that require attention.
2) The second step involves a purposeful involvement of field supervisors for the assessment of the field conditions through planned inspections and drive-around with them.
3) The job factors and conditions as well as the attitude of equipment operators are taken note of as the inspection takes place.
4) The Engineer asks relevant questions on the topic and guides the field supervisor through simple questions to identify causes of inefficiency and loss as well as proposed solutions based on the collective observations; and
5) Through brainstorming, a result is established for causes-and-effects of operational issues on the topic being investigated and solutions obtained out.

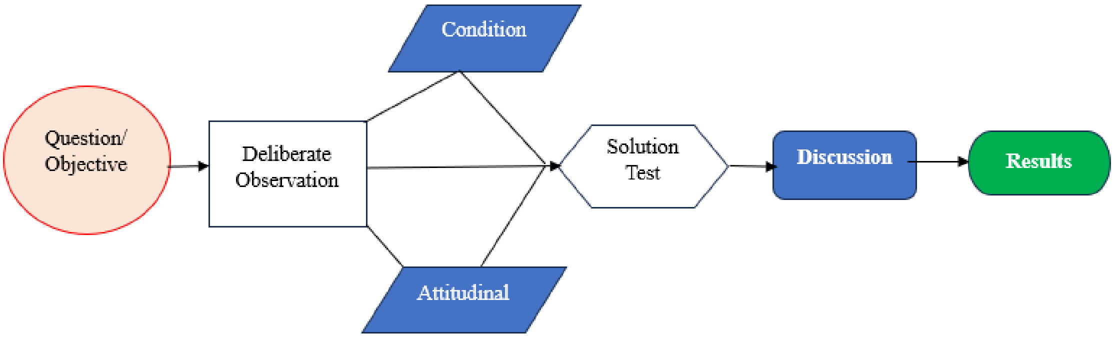

Figure 1. *Schematic Diagram of the S-FEA.*

3. Results and Discussions

3.1. Field Observations and Analyses

The collected data, which includes general information such as the machine type (CAT785C Haul Truck), truck capacity (141 tonnes), tyre size (33.00R51), number of tyres per machine (6), and tyre brands used at the mine (Michelin and Bridgestone), was assembled and analyzed to inform decision-making. The performance of the tyres on twenty-four (24) CAT 785C haul trucks in service from January 2010 to December 2020 was closely observed, with downtime due to tyre failures and the respective failure modes being recorded. Figure 2 illustrates the monthly count of tyre replacements during this period. Notably, the average operational life of all failed tyres was 4,202 hours, significantly less than the projected 7,000 hours. Figure 3 depicts the yearly average downtime of the machine due to tyre failures.

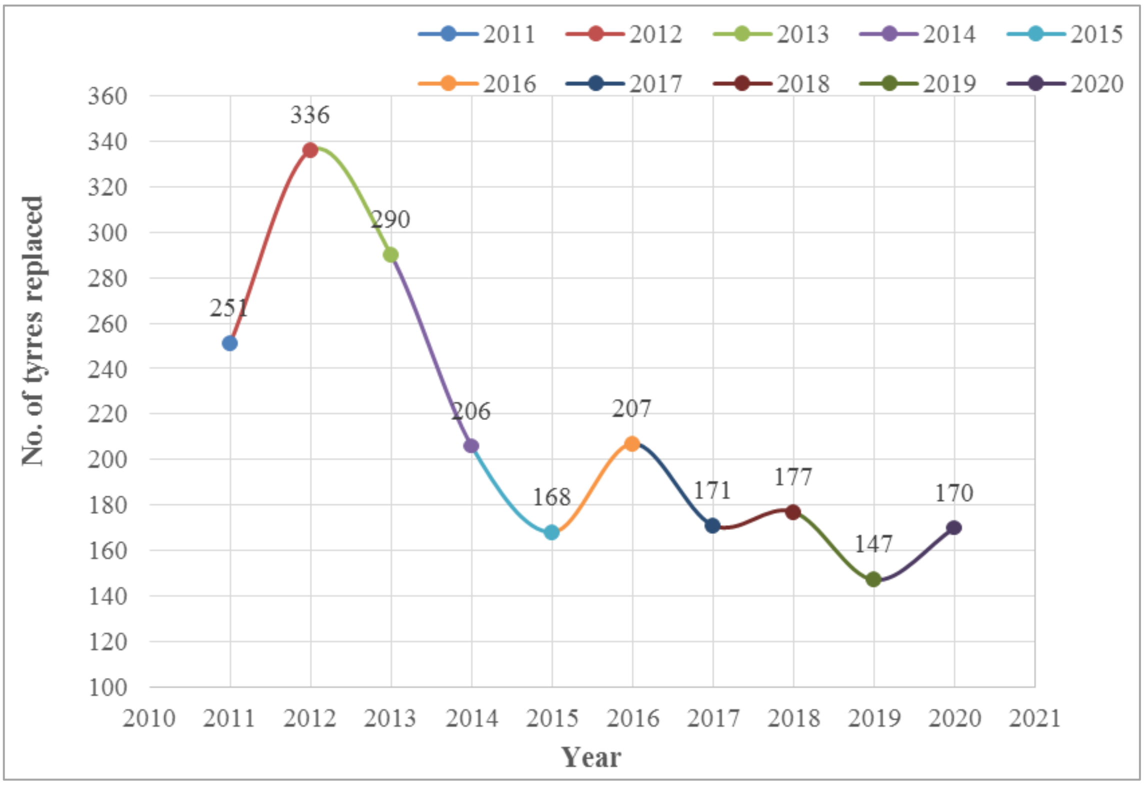

Figure 2. *Tyres Replaced per Year.*

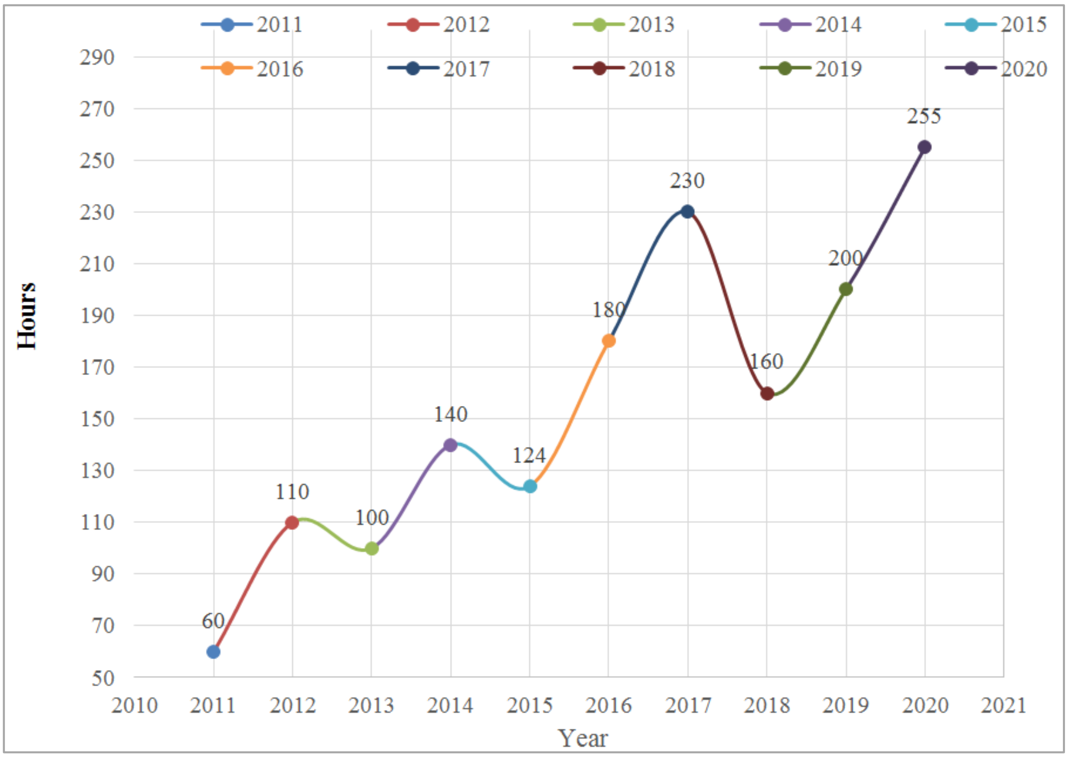

Figure 3*. Tyre Downtime per Year.*

The data analysis in Figure 3 shows the haul truck tyre downtime for the tyres that failed from 2010 to 2020. Generally, the trend of downtime due to tyre failures is increasing from year to year, with the highest tyre downtime being recorded in 2017 and 2020, respectively. This trend is quite alarming and calls for an assessment such as this. It was observed that the extended downtime resulted from the new tyre size on the mine. Figure 3 shows tyre downtime against failure events. The mode of tyre failures and their frequencies were obtained as presented in Table 1 and graphically illustrated in Figure 3. It is worth noting that all these tyres failed during the period under review without achieving the mine's 7 000 operational hours.

Table 1*. Tyre Failure Modes and their Frequencies.*

Tyre Failure Type	Frequency	Tyre Failure Type	Frequency
Liner/Tube/Rust Band Failure	1	Impact	52
Radial Cracks	1	Shoulder Cut	79
Seized Brakes	2	Repair Failure	92
Accidental Damage	7	Worn	159
Heat Separation	7	Separation	169
Bead Damage	12	Tread Cut	340
Foreign Object/Puncture	13	Sidewall Cut	355
Tread Cut Separation	30	Tread Chunking	803

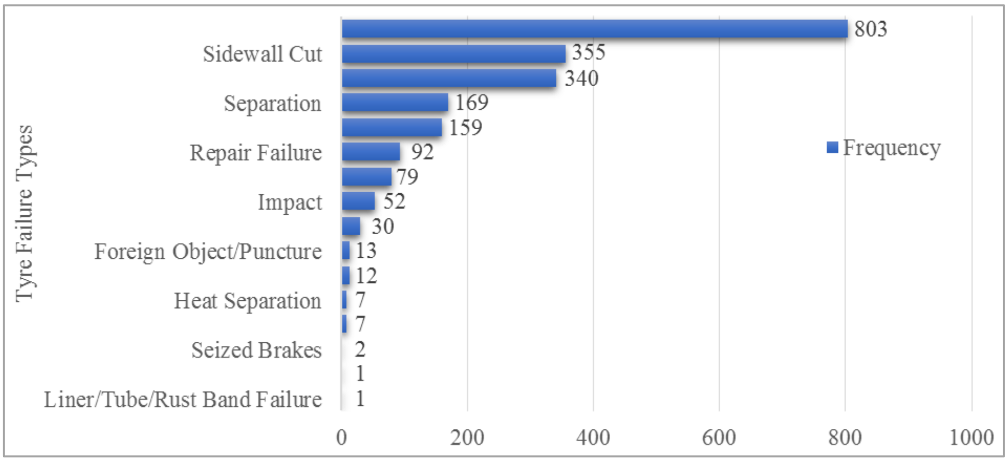

Figure 4. Tyre Failure Mode.

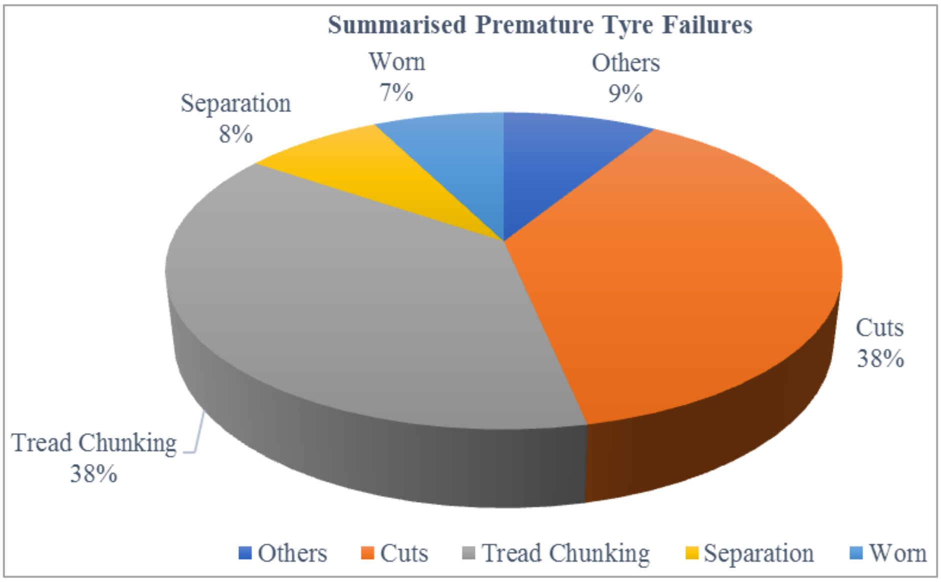

Figure 5. Major Premature Tyre Failure Types at NAM.

3.2. Causes of Premature Tyre Failure at NAM

From Figure 4, the premature tyre failures were further grouped into five to undertake qualitative research through field surveys/tours, haul truck tyre observations, and interviews with junior staff, supervisors, general foremen, and superintendents from both mine operations unit and maintenance department. This research is to aid in identifying the major causes of each of the premature tyre failure modes, which have been summarised and presented in Figure 5.

3.2.1. Types and Causes of Tyre Cuts in NAM

Three different premature tyre failures have been categorised according to the position of the cut. These are sidewall cut, shoulder cut, and tread cut.

Sidewall cut

Tyre sidewalls are built to be strong and to withstand the extreme forces and pressures often experienced while driving. This helps to keep the haul truck stable. Though the tyre sidewalls are built to be strong, they can be damaged in several ways, as shown in Figure 6. A literature review was done to identify the major causes of Tyre sidewall cut/damage, which apply to NAM, Ghana. These are: Hitting a kerb (HK); Sharp objects in the work area (SWA); Rocks caught between the dual wheels (RDW); Operator negligence (ON); Under inflation or overloading (UO) and Poor underfoot conditions or water (PUC). Field observations were undertaken from 2010 to 2020 in the Subika and Awonsu pits to identify the most frequent cause of the haul truck tyre's sidewall cut/damage. A total of 42 haul truck tyre sidewall cuts/damage was recorded over the 12 months of study, and the breakdown of the result is present in Figure 7. The field study showed that among the causes of tyre sidewall cut/damage at NAM, paramount among them are poor underfoot conditions or water; sharp objects in the work area, hitting a kerb and operators' negligence.

Figure 6. *Haul Truck Tyre Sidewall Cut.*

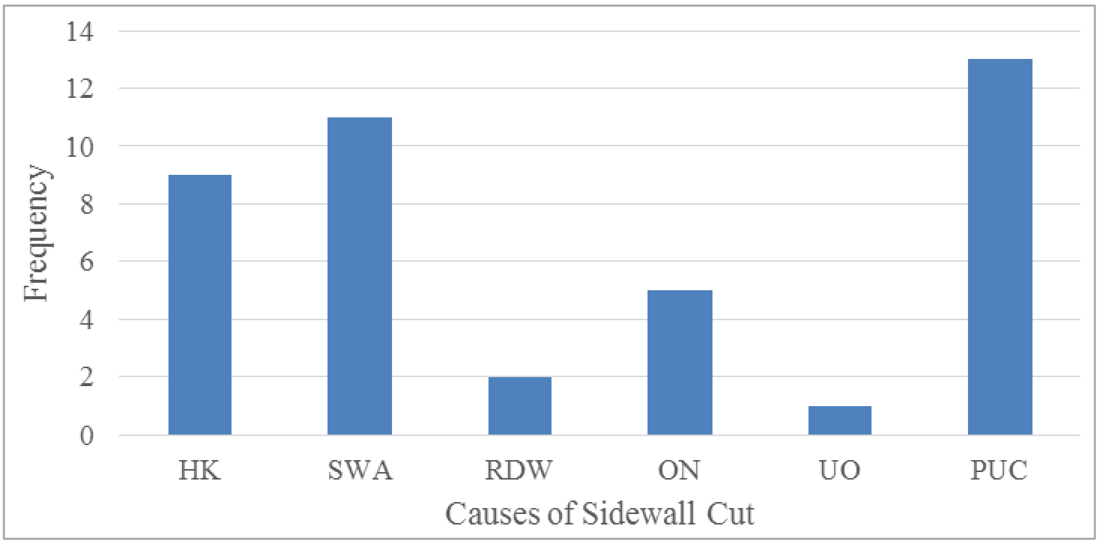

Figure 7. *Haul Truck Tyre Sidewall Cut.*

Shoulder cut

In interviews with field workers, supervisors and superintendents from the mine operation and tyre maintenance departments, the following were identified as contributing factors: Spillage and foreign objects; Course material on the berm/windrow; Poor pit conditions; and aggravated by water. Following the identified causes of shoulder cuts, a field study was conducted in the Subika and Awonsu pits of NAM, Ghana. The data collected recorded 8 cases over the period of 12 months. The breakdown is presented in Figure 9. It was clear that the major causes of premature tyre failure by shoulder cut are aggravations by water and poor pit conditions. Figure 8 below shows a cut in the shoulder area but no casing damage.

Figure 8. *Haul Truck Tyre Shoulder Cut.*

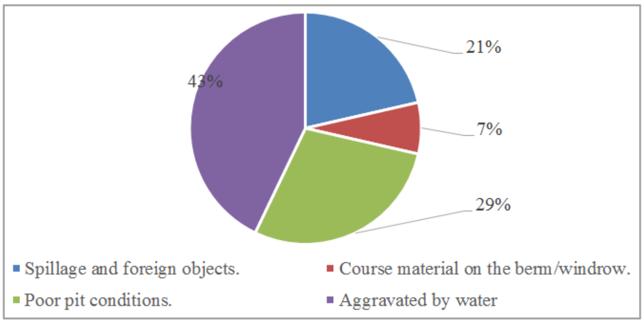

Figure 9. *Causes of Haul Truck Tyre Shoulder Cut.*

Tread cut

A typical example of a cut in the tread crown but not penetrating the casing is presented in Figure 10. The causative factors of the tread cut include Improper inflation or underfoot conditions (IUC); Aggravated by water (AW); Sharp objects in the work area (SWA); and spinning, skidding or sliding (SSS). The number of cases recorded for the factors that cause tread cut was taken and analysed in Figure 11.

Figure 10. *Tread Cut.*

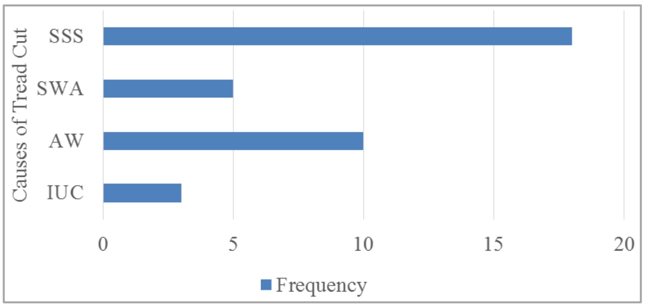

Figure 11. *Category of the Major Causes of Haul Truck Tyre Tread Cut.*

3.2.2. Causes of Tyre Tread Chunking in NAM

Chunking refers to the phenomenon of missing tyre tread sections, as depicted in Figure 12. It appears the tread has been removed in pieces or ripped away from arbitrary locations on the tyre. In interviews with relevant workforces, contributing factors revealed the following: Improper inflation (II); Underfoot conditions (UC); Excessive speeding (ES); Aggressive braking (AB); Overloading (OL); Mismatched diameters on dual tyre machines (MD); and spinning, skidding or high torque (SSH). Data collected over a period of 12 months, from January 2020 to December 2020, on Haul truck tyre premature failure resulting from tread chunking has been analysed and presented in Figure 13.

Figure 12. *Haul Truck Tyre Tread Chunking.*

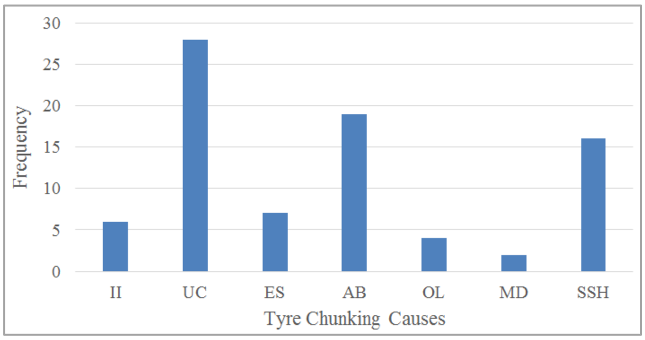

Figure 13. *Causes of Tread Chunking of Haul Truck Tyres at NAM, Ghana.*

3.2.3. Causes of Tyre Separation in NAM

Tyre tread separation is a dangerous condition wherein the tyre's tread separates itself from the casing or body of the tyre. Thus, it is the deformation of the tread area due to the tread band separating from the casing ply, as shown in Figure 14. The contributing factors are excessive heat generation (EHG), exceeding the TKPH for the tyres (ETT), excessive cornering (EC), incorrect inflation or speed (IIS), and overloading (OL). Having identified the major causes of the haul truck tyre failure by separation, fieldwork was done over 12 months – January 2020 to December 2020, to obtain data regarding the most applicable causes of tyre separation at NAM, Ghana. The result obtained has been summarised in Figure 15.

Figure 14. *Haul Truck Tyre Separation.*

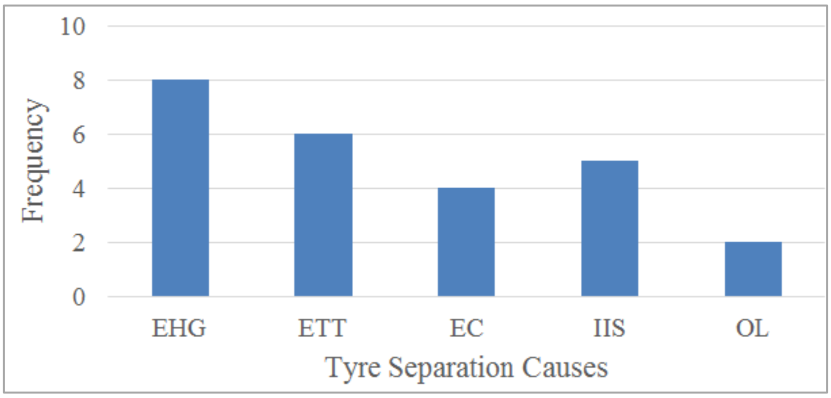

Figure 15. *Causes of Haul Truck Tyre Separation.*

3.2.4. Causes of Tyre Worn in NAM

Tyre wear results from on or beyond the bottom of the tread grooves. Small bars of rubber running across the grooves in between the tread – called tread wear indicators – point out that the tyre is worn out. If the tread is worn down to these bars on any part of the tyre, it's worn out, unroadworthy, and needs to be replaced. An example of tyre worn is presented in Figure 16.

Figure 16. *Tyre Worn Out.*

According to the tyre damage report acquired from the maintenance department, factors contributing to the wear of haul truck tyres include i) improper inflation or overloading, ii) unfavourable operating conditions such as water or undulations, iii) defects in repairs, iv) repairs conducted outside recommended specifications, v) subpar workmanship, and vi) secondary damage caused by the repair process. A field study on the causes of haul truck tyres worn out at NAM, Ghana, was carried out by recording the various factors that contributed to tyre worn out from January 2020 to December 2020. The result is presented in Figure 17.

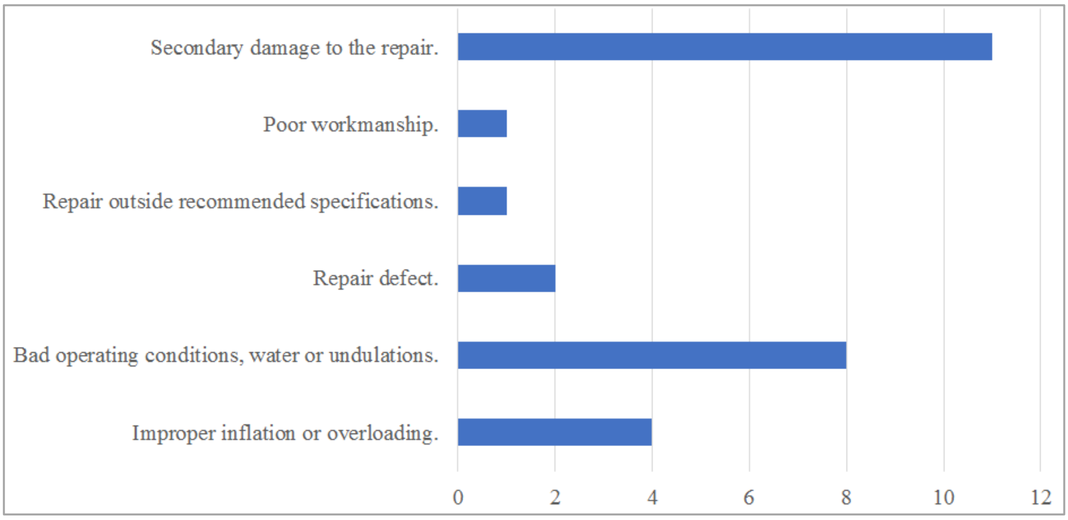

Figure 17. *Major Causes of Tyre Worn at NAM.*

3.3. Trend of the Causes of Premature Tyre Failure

During the data collection and observation, it was noticed that more cases were recorded in certain months. This necessitated tallying the total tyre failures recorded for each month during the study to identify any hidden trend in premature tyre failures within the year. The study was conducted from January 2020 to December 2020. The summary is presented in Figure 18.

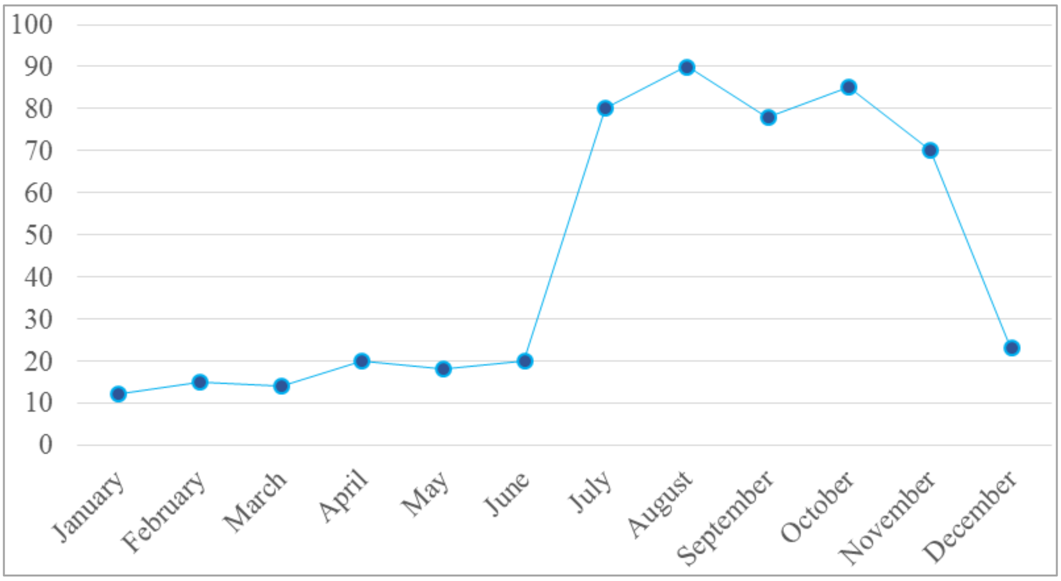

Figure 18. *Premature Tyre Failure Trend in NAM, Ghana.*

With the Ahafo region being part of the forest belt of Ghana, it records its wet season from July to November, whiles the dry season starts from December to April. The trend indicates that most of the premature tyre failures were recorded during the wet seasons as compared to the dry seasons.

3.4. NAM Tyre Maintenance Practices

After the determination of the premature tyre failure types and their causes at the site, further investigation into the maintenance culture of the mine was done to identify lapses that account for the mine's tyre failures. Two types of haul truck tyres were used by NAM, namely Michelin and Bridgestone. The number of each brand purchases during the period of January 2010 to December 2020 is summarised as shown in Table 2.

Table 2. Type of Tyres Bought.

Tyre Brand	Number
Bridgestone	2031
Michelin	91
Grand Total	2122

Both Michelin and Bridgestone offer quality haul truck tyres to NAM; however, the mine's preference of Bridgestone to Michelin was based on favourable management conditions and quick delivery as opposed to Michelin, which prefers to deal with corporations/companies at large and not individual Mining sites. Based on interviews with the workforce, supervisors, general foremen and superintendents from both the mine operations and maintenance departments, coupled with the observations made during the 12 months of field study – January 2020 to December 2020, the tyre maintenance practices adopted by NAM can be categorised into two: operational maintenance and storage and repair.

3.4.1. Operational Maintenance Practices

The mine has adopted four main concerns regarding improving the operational life of the haul truck tyres. They are tyre rotation and tyre air pressure setting at installation, road maintenance and dust suspension.

Tyre rotation

Tyre rotation, as detailed by Li *et al.*, [8] and Zhou *et al.* [10], entails transferring a tyre from one wheel position to another on either the same or a different haul truck, serving several essential functions. The authors added that this activity does not only ensures safety by supporting the driver's cab with front tyres but also mandates tyre rematching when a 10 mm tread depth difference is observed, assists in upholding consistent tyre load and air pressure, and contributes to decreasing tyre failures, subsequently extending their durability. At the NAM, new tyres are typically installed in the front positions, while the older ones are moved to the rear. The mine adopts a variety of rotation strategies, which include rotating after the tyre wear reaches 35%, rotating when the tread depth falls below 70%, and rotating based on the running hours of the tyre. This study adopts the tyre wheel position acronyms used by NAM, Ghana, which were originally introduced by Zhou *et al.* [9, 10] namely: LF (left front), RF (right front), LRO (left rear outside), LRI (left rear inside), RRO (right rear outside), and RRI (right rear inside). The mine also implements specific tyre rotation sequences, depicted in Figure 19. These sequences include rotating to the same side inside position (SI) of the same or a different truck, for example from RF to RRI; to the same side outside position (SO), e.g., from RF to RRO; to the opposite side inside position (OI), e.g., from RF to LRI; and to the opposite side outside position (OO), e.g., from RF to LRO.

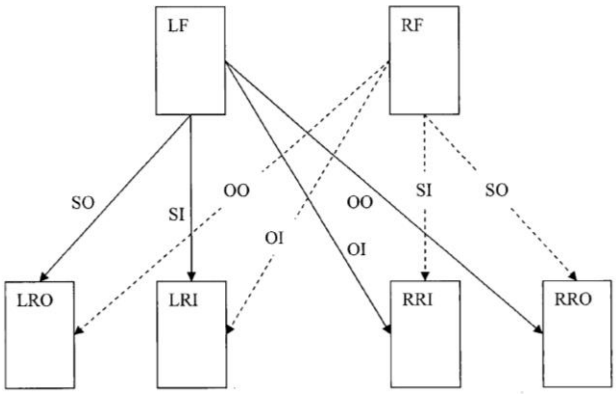

Figure 19. Tyre Rotation Types Adopted by NAM. [10]

Tyre air pressure setting at installation.

NAM ensures regular air pressure and tread depth checks and scrap tyre inspection because they provide valuable information as the basis for data input into iTruck – a tyre management software handled by a third part company.

Haulage road maintenance

One of the chief culprits of tyre failures is spillage from off-highway haulage trucks. For this reason, it is always expedient that the grader grades the haulage routes periodically to remove loose debris.

Dust suspension

Dust suppression, like well-graded and watered haul roads, ensures visibility and clarity. During haulage, dust thrown up by the dump trucks is suspended in the air, which intends to reduce visibility and mobility, posing a safety hazard. For this reason, the mine has watering tankers that regularly water to ensure no dust suspension on the haulage roads.

3.4.2. Storage and Repair Practices

Brand-new tyres purchased are arranged and stored in an open area, as seen in Figure 20. In cases where there are old tyres that have been repaired and are worthy of being reused, the arrangement of the tyres is made so that the old but repaired tyres are placed in front of the brand-new ones.

Figure 20. *Brand-New Tyres Arranged and Stored at NAM Site.*

Repairing rubber tyres from Caterpillar haul truck mining vehicle in maintenance workshop to maximise tyre life. Prematurely failed haul truck tyres that are not spoilt repairs are sent to the Mine's maintenance workshop to be repaired and reused. A pneumatic wire brush is used to clean up the damage from the inside of the tyre before repair, as shown in Figure 21. At NAM, the commonly used method for repairing haul truck tyres is the internal patch method. The tyre is checked to identify the damaged location, the damaged area is then planished, and glue is applied around the hole. A special rubber patch is attached to the damaged area and pressed firmly. After that, a layer of protective glue is smeared in the area and allowed to dry. The tyres are then stored for reuse. Repairing old tyres helps maximise tyre life during supply shortages and decreases operational costs. However, the disadvantage of this method is that the damaged parts are easily corroded by rainwater and other pollutants.

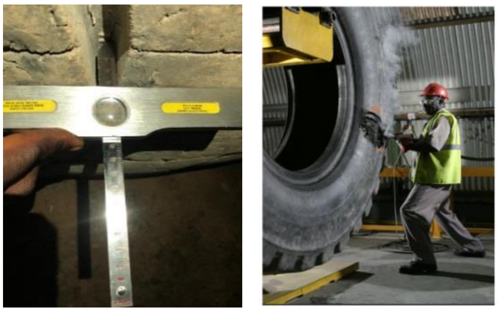

Figure 21. *Haul Truck Tyre Being Repaired at NAM Site.*

3.4.3. Suggestive Measure to Optimise the Tyre Life

Upon meticulous investigation of the mine's current tyre maintenance practices, numerous shortcomings were identified, contributing to a significant number of premature tyre failures and impeding the achievement of their 7000-hour operational tyre life target. To address the primary causes of premature tyre failures, a set of comprehensive and specific recommendations have been proposed. For the latter, critical question process maps (illustrated in Figures 22-27) have been devised for each major cause of premature tyre failure at NAM, requiring routine examination by truck operators and the maintenance department.

One of the most effective tyre maintenance practices the mine can adopt is ensuring proper tyre inflation, which not only extends casing life but also yields additional benefits. Tyre inflation levels should be inspected at least daily or, ideally, before each shift, avoiding both overinflation and underinflation. While overinflation leads to uneven wear, underinflation results in increased tyre flexing and heat build-up. Furthermore, tyres must be examined for inflation issues, tread depth, cuts, nicks, and mismatched tyres before the commencement of every shift, as fleet surveys can identify and rectify overlooked issues before they become costly problems [11].

Adherence to each haul truck tyre's specific ton-mile-per-hour (TMPH) rating, which determines the tyre's load-bearing capacity at a particular speed, is crucial for optimising performance and prolonging tyre service life [12], employing GPS tracking units on all vehicles and utilising the collected data to calculate TMPH will help NAM ensure its tyres are operating within their designed capacity. Moreover, integrating this data on tyre load, vehicle speed, inflation levels, tread depth, and other essential factors into a robust online tyre management system will enable effective tracking of tyre service hours and facilitate replacement planning and budgeting [13].

When replacing dual haul truck tyres, it is imperative to account for even the slightest disparities in tread depths and patterns to prevent slipping, scrubbing, overheating, and undue stress on the truck's mechanical systems [14]. Accurate measurement of the tyre's static loaded radius (SLR) and matching it with the appropriate SLR ensures optimal dual tyre performance. NAM is also advised to adopt the mushroom nail repair method, which provides a safer and more effective repair compared to their current internal patch method [15]. Lastly, it is crucial to remain vigilant of risks such as clipping the curb, falling rocks, and debris when working or driving near a hanging wall, as these hazards can result in tyre damage.

1) Sidewall cut.

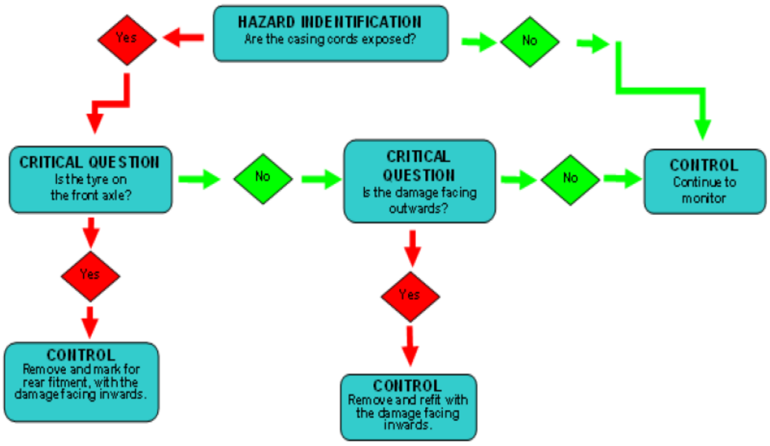

Figure 22. Critical Questions Process Map for Sidewall Cut.

2) Shoulder cut

Figure 23. Process Map for the Shoulder Cut.

3) Tread cut

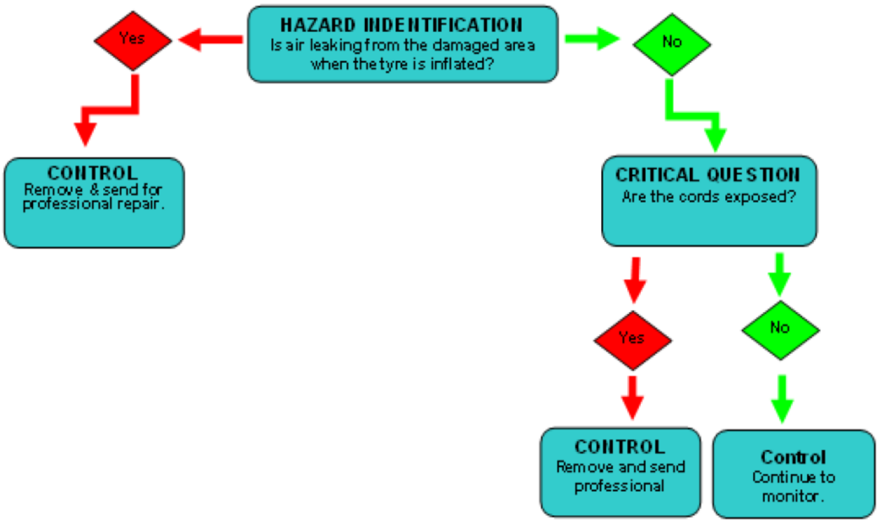

Figure 24. Process Map for Tread Cut.

4) Tread chunking

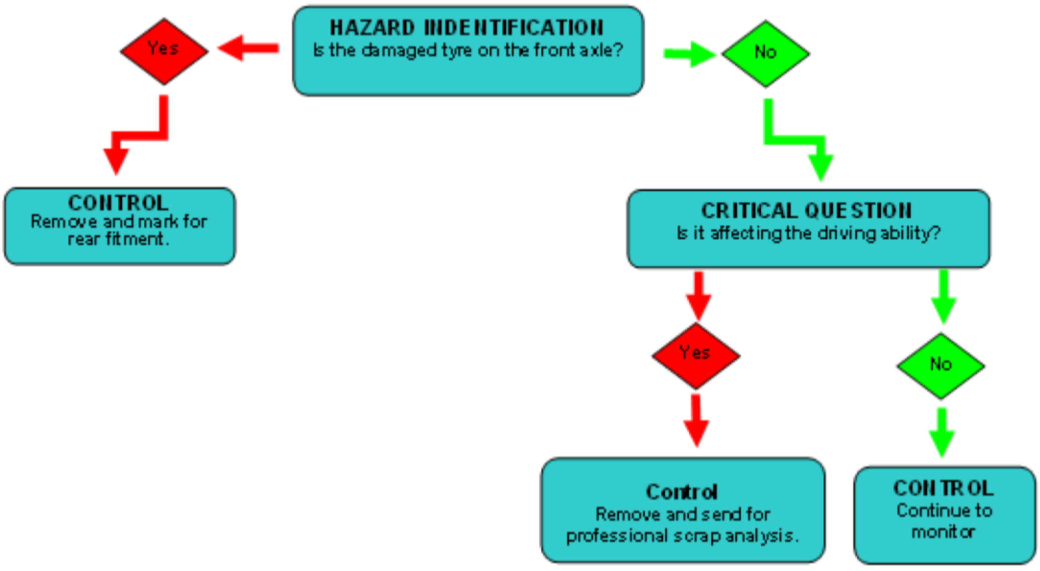

Figure 25*. Process Map for Tread Chunking.*

5) Separation

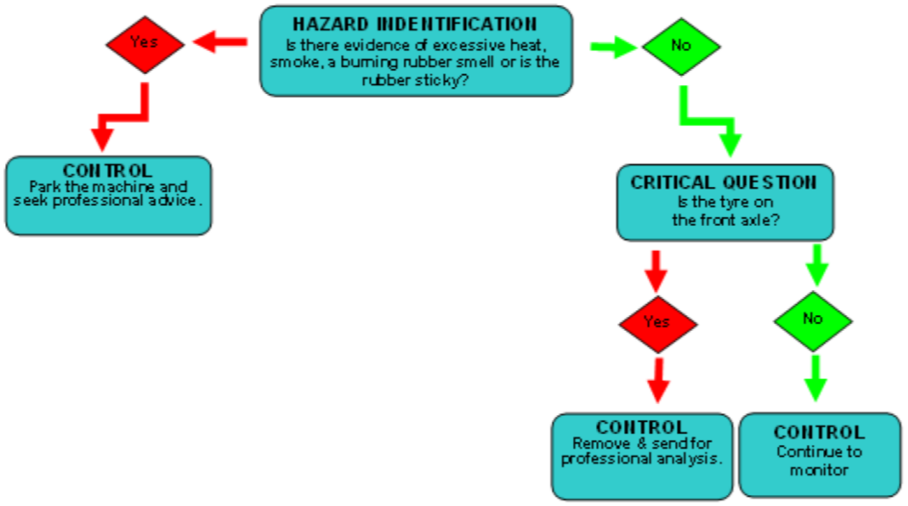

Figure 26*. Process Map for Separation.*

6) Worn

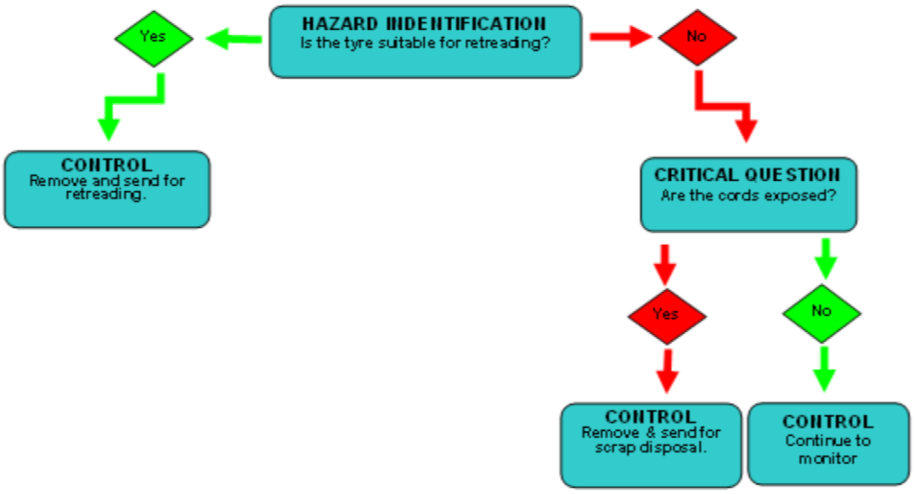

Figure 27. Process Map for Worn.

4. Conclusions

Based on the comprehensive fieldwork, data collection, analysis, and discussions, it has been concluded that the mine's premature tyre failures over the past decade can be attributed to various factors, including accidental damage, bead damage, separation, puncture, heat separation, impact, liner/tube/rust band failure, radial cracks, repair failure, seized brakes, shoulder cut, sidewall cut, tread chunking, tread cut, and worn tyres. A thorough examination of these tyre failure types facilitated the identification of the most frequent occurrences and their underlying causes based on observations conducted from January to December 2020. The four most common tyre failure types - cut, tread chunking, separated and worn - were found to be predominantly caused by secondary damage to the repair area, unfavourable operating conditions, water or undulations, improper inflation, overloading, excessive heat generation, exceeding the TKPH for the tyres, excessive cornering, incorrect inflation or speed, spinning, skidding, high torque, underfoot conditions, aggressive braking, excessive speeding, mismatched diameters on dual tyre machines, hitting a curb, sharp objects in the work area, poor underfoot conditions, operator negligence, rocks caught between the dual wheels, aggravation by water, poor pit conditions, spillage, foreign objects, course material on the berm/windrow, and spinning, skidding, or sliding.

A higher incidence of tyre failures was observed during wet seasons compared to dry seasons. Despite the mine adopting credible tyre maintenance practices such as tyre rotation, tyre air pressure setting at installation, road maintenance, and dust suspension, these measures were found insufficient in preventing premature tyre failures, necessitating a more robust tyre management system. The current tyre storage and repair practices were deemed suboptimal, as new tyres are stored in open spaces under direct sunlight, accelerating natural degradation due to exposure to oxygen, ozone, and sunlight. Furthermore, the study recommended replacing the internal patch method used for repairing old tyres with a more reliable repair method.

Abbreviations

AW: Aggravated by Water
EC: Excessive Cornering
EHG: Excessive Heat Generation
ETT: Exceeding the TKPH for the Tyres
HK: Hitting a Kerb
IIS: Incorrect Inflation or Speed
IUC: Improper Inflation or Underfoot Conditions
LF: Left Front
LRI: Left Rear Inside
LRO: Left Rear Outside
NAM: Newmont Ahafo Mine
OI: Opposite Side Inside Position
OL: Over-Loading
ON: Operator Negligence
PUC: Poor Underfoot Conditions or Water
RDW: Rocks Caught Between the Dual Wheels
RF: Right Front
RRI: Right Rear Inside
RRO: Right Rear Outside
S-FEA: Supervisor-Field Engineering Approach
SI: Same Side Inside Position
SO: Same Side Outside Position
SSS: Spinning, Skidding or Sliding
SWA: Sharp Objects in the Work Area
THPH: Tonne Kilometres Per Hour
TMPH: Ton Mile Per Hour
UO: Under Inflation or Overloading
VIMS: Vehicle Information Management System

Conflicts of Interest

The authors declare no conflicts interest.

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