



# A critical investigation into tyre life on an iron ore haulage system

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Paper written on project work carried out in partial fulfilment of B. Eng. (Mining Engineering)

## Synopsis

A downward trend in tyre life on haul trucks at an open pit iron ore mine prompted an investigation into the current tyre management strategy in order to improve tyre life. 'Best practice' was compared to the current tyre management strategy at the mine to determine aspects that could be improved. Aspects that showed significant room for improvement included employee tyre awareness, tyre pressure maintenance, and road conditions. For each of these aspects a plausible alternative was suggested.

A new tyre management strategy was formulated as a step-by-step guide on how to implement the proposed changes. Each step introduces new initiatives but at the same time builds on the previous step's success. A sensitivity analyses was performed to determine the impact of the proposed changes, with the variables being the reduction in the percentage of premature tyre failure, and the reduction of the site wear rate.

The 'most likely' scenario showed an increase in tyre life of 41% for the Komatsu 730 trucks and 105% for the CAT 777 trucks if the entire tyre management model is implemented. This would result in a possible annual saving related to tyre usage of R9.2 million.

## Keywords

tyre life, tyre management, wear rate, premature tyre failure, tyre awareness.

## Overview

The study focused on the tyre life on the main haul fleet at an open pit iron ore mine. The haul fleet consisted of 17 Komatsu 730 (180 t) haul trucks and 12 CAT 777 (90 t) haul trucks.

The haulage operation consists entirely of tyre-based haul trucks. Five per cent of the total mining budget is related to tyre costs. Since 2012 there has been a steady decrease in tyre life as measured in operating hours (Figure 1) due to the high percentage of tyres that fail prematurely. In 2014 a total of 41% of all tyres failed prematurely and 61% were classified as 'worn out'.

## Methodology and objectives

The purpose of this study was to evaluate the current tyre management strategy at the mine and to identify possible aspects that can be altered in order to increase tyre life. A detailed breakdown of the objectives and methodologies followed during the project is shown in Table I.

## Results

Two main methods of increasing tyre life were identified:

- ▶ Method A: reducing the site wear rate of tyres, as measured in millimetres per 1000 hours
- ▶ Method B: reducing the percentage of tyres that fail prematurely.

## Tyre wear rate

The most common reason to scrap a tyre is simply because it is worn out. In 2014 it was determined that 59% of all tyres scrapped were classified as worn out. A tyre that is worn out has reached its maximum life achievable due to a specific wear rate. The wear rate at the mine in terms of each tyre classification is shown in Table II. The data shows that the achievable tyre life for each truck is significantly higher than the recorded tyre life. This is due to abnormal wear of tyres or tyres that fail prematurely.

## Premature tyre failure

In 2014 it was determined that 41% of all tyres failed prematurely. This is an increase of 8% from the previous year. The increasing number of tyres that fail prematurely is the biggest contributor to the decreasing trend in tyre life over the last two years. If fewer tyres fail prematurely, more tyres will be worn out and therefore the overall tyre life will be increased. Figure 2 shows the monthly costs associated with each premature failure mode for a period from 2012 to 2014. In November 2014 the year-to-date premature failure cost totalled R2.5 million (Jordaan, 2014), an increase of 92% from November 2013 (R1.3 million).

The cost associated with tyre failure is based on the value of remaining tread on a

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*Table I*  
**Objectives and methodologies**

Objective	Methodology
Quantify the problem	The tyre performance history was thoroughly investigated to: <ul style="list-style-type: none"> <li>• Determine the tyre life trend and outlook</li> <li>• Determine the current tyre-associated targets</li> <li>• Determine the cost of premature tyre failure</li> <li>• Determine the main causes of premature tyre failure through analysing component failure reports and general monthly tyre management reports</li> </ul>
Identify all the parameters that can influence tyre life	A literature survey was conducted to: <ul style="list-style-type: none"> <li>• Determine the different factors that influence tyre life</li> <li>• Identify the main element of a proper tyre management strategy (best practice)</li> </ul>
Determine the impact of each parameter on tyre life	Each factor that was identified through the literature survey was investigated to determine the extent of the impact if not managed properly
Investigate the operational practises.	The current tyre management strategy was investigated and analysed through: <ul style="list-style-type: none"> <li>• On-site observations</li> <li>• Historical tyre failure data</li> <li>• Historical road and pit conditions data</li> </ul>
Determine which aspects of the current tyre management strategy can be altered to comply with best practice in order to increase the tyre life of both the waste and ore haul trucks	After the evaluation of each aspect of the current tyre management strategy a plausible alteration was suggested, if found unsatisfactory
Determine the impact of the proposed changes.	The qualitative impact of the proposed alterations was estimated and the financial impact thereof was calculated.

*Table II*  
**Tyre wear rate**

Truck	Tyre size	Target tyre life (hours)	Tread available (mm)	Wear rate (mm per 1000 hours)		Tyre life at actual wear rate (hours)
				To achieve target tyre life	Actual	
Komatsu 730 CAT 777	40.00×R57	7200	87.0	12.1	9.0	9667
	27.00×49	5600	79.0	14.1	8.0	9875

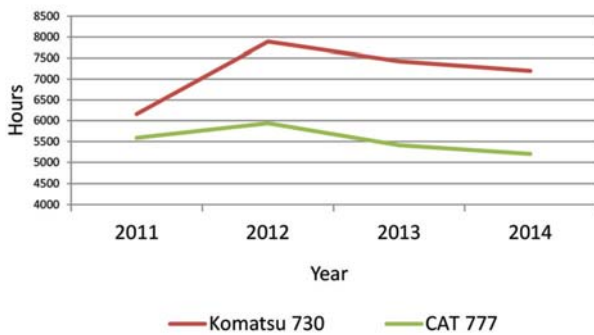


Figure 1 – Tyre life trends

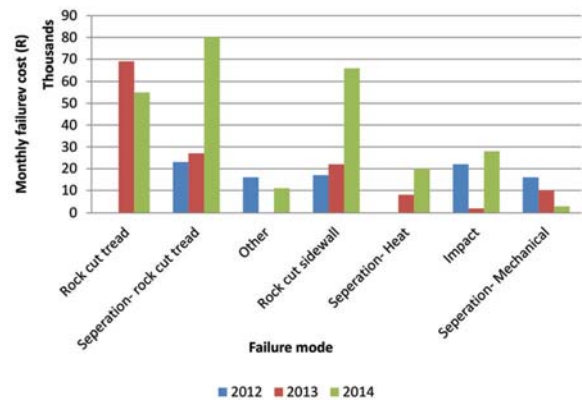


Figure 2 – Monthly cost of premature tyre failure

scrapped tyre, which is referred to as lost tread. The lost tread value of scrapped tyres for 2014 was in the range of R5.5–6.0 million. This is the total value of tread left on all the tyres that were scrapped in the year. Lost tread is caused not only by the various premature failure modes, but also abnormal wear of tyres.

### Literature survey

From the literature survey it was determined that a single tyre failure mode cannot be associated with a certain aspect of tyre management. This led to the conclusion that the entire

tyre management strategy has to be aligned with ‘best practice’ in order to significantly improve tyre life. The results from the literature survey suggested that a ‘best practice’ tyre management strategy should consist of the key elements that are summarized in Table III.

### Operational practices

The operational practices at the mine were then evaluated to determine whether the following elements were adequately addressed.

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Table III

## Key elements of 'best practice' tyre management

Maintenance	<ul style="list-style-type: none"> <li>• Tyre pressure maintenance</li> <li>• Haul road maintenance</li> <li>• Tyre maintenance</li> <li>• Vehicle maintenance</li> </ul>
Haul road design	<ul style="list-style-type: none"> <li>• Horizontal and vertical alignment</li> <li>• Cross fall</li> <li>• Drainage</li> <li>• Super elevation</li> <li>• Curve radius</li> <li>• Road construction</li> <li>• Road width</li> </ul>
Loading practice	The payload policy of the haul truck manufacturer should be strictly adhered to and monitored
Vehicle speed	Specific attention to maximum speed, acceleration, and braking
Tons-kilometres per hour (TKPH)	The TKPH rating of the tyre should never be exceeded due to the site work load (speed and payload)
Matching of tyres	In order to ensure even wear, tyre assemblies operating as dual pairs must: <ul style="list-style-type: none"> <li>• Have the same outside diameter</li> <li>• Be from the same manufacturer</li> <li>• Be of the same type (industry code).</li> </ul>

### Matching of tyres

The tyre pairs on the rear axle of a truck need to match in order to ensure even wear of both tyres. The mine does this well, as matching spare tyre pairs are kept in a tyre bank. The tyre bank is kept well stocked by replacing tyres on the front axle after 30% tread wear with new tyres (Jordaan, 2014). Pairs of equally worn tyres are made up from the replaced tyres and stored in the tyre bank. The mine keeps a well-stocked tyre bank, with 99 Komatsu 730 tyres and 69 CAT 777 tyres recorded during November 2014.

### TKPH

TKPH is a measure of the heat buildup in a tyre due to the load it has to carry and the speed at which it is travelling. The TKPH is currently not being monitored. A TKPH study was done to determine the suitability of the current tyres for the working conditions. The results are summarized in Table IV. The table shows the average TKPH of the tyres on the axle with the heaviest load, thus showing the average maximum TKPH of each cycle. From Table IV it is clear that the actual TKPH for tyre types is well below the TKPH rating of the manufacturer. This suggests that the correct tyres for each truck type in terms of TKPH are being used, and that the tyres are not failing prematurely due to the work load.

### Average vehicle speed

The average vehicle speed is well within the limits prescribed by the mine. There is, however, no means of live monitoring of acceleration and braking. This is where the real danger to tyres lies.

Some elements of the mine's current tyre management strategy showed room for improvement.

### Tyre pressure maintenance

Only 90% of tyres are correctly inflated at any given time – thus 20 tyres in the haul fleet are at an incorrect tyre pressure. To what extent these tyres are incorrectly inflated is unknown. A sensitivity analysis was done and the results were based on the assumption that the 10% of tyres that are at an incorrect tyre pressure are 90% inflated. Results would

differ if the actual amount of incorrect inflation was known. According to the tyre management contractor (Woodman, 2002), 10% underinflation in very demanding conditions such as an iron ore mine can lead to a reduction in tyre life of 27%. Another concern is that an individual tyre is only checked seven times per month, and not the minimum required frequency of once a day.

### Payload control

It was found that the mine adheres strictly to the payload policy of Komatsu (2014) in the case of the Komatsu 730 trucks, due to the built-in system on those trucks. This is, however, not the case for the CAT 777 truck. The payload study revealed that only 44% of all loads were less than the optimum load of 90.5 t. Of the 56% of the loads that exceeded the optimum, 13% were overloaded more than 20%. This data is summarized in Figure 3.

Table IV

### TKPH study results

Truck	Tyre type	TKPH rating	Actual site TKPH
Komatsu 730E - 7	40.00xR57	960	523.9
Komatsu 730E - 8	40.00xR57	960	785.7
CAT 777	27.00x49	480	386.4

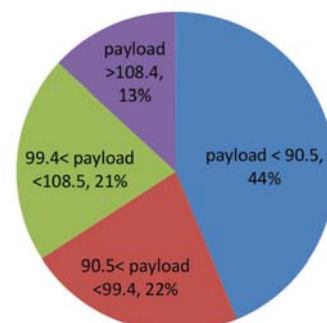


Figure 3 – CAT 777 no. 5 payload distribution

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## Road conditions

Road conditions can be assessed according to two categories of road – permanent and in-pit. Currently, the permanent roads are monitored and assessed using an assessment and reporting system. This system has a number of drawbacks, the main one being the lack of communication between assessor and operator who can correct the error. A new system is proposed (Dust-a-Side, 2013) that will fill the communication gap. This new system will make continuous road evaluation possible, because road defects can be identified and logged by using a handheld device. This information is immediately shared with the operators of road maintenance equipment by using wireless technology.

## Tyre awareness

The main challenge at the mine is not the tyre management strategy, but the level of tyre awareness amongst employees. Figure 4 shows the results of a questionnaire completed by employees of various levels. The employees would have known the correct answers to the questions if their level of tyre awareness was adequate. The most concerning fact is that the operators, who have the largest impact on tyre life, showed the lowest level of tyre awareness.

If tyre awareness increases amongst employees, common operator errors would decrease. These include:

- Reversing onto the muck pile while loading
- Speeding around corners while loaded
- Spillage in the loading area
- Driving through spillage and water
- Incorrect loading practices.

## Analysis of results

The results were reworked into a physical and realistic implementable tyre management model. The model consists of a step-by-step strategy, with different aspects of tyre management to be implemented or changed at specific stages. The model focuses on the three main elements of the current tyre management strategy that showed room for improvement. These are:

- Tyre awareness
- Tyre pressure maintenance
- Road conditions.

The tyre management model consists of three phases. Each phase uses different tools to improve tyre management, but at the same time builds on the previous phase. Table V describes the initiatives in each phase. It also indicates which tyre life improvement method (A or B) each initiative will have the most significant positive effect on.

## Phase 1: Working with people

The employee mind-set and tyre awareness have to change before large sums of capital are spent on technology in an effort to increase tyre life. Phase 1 consisted of most of the changes to the current tyre management strategy, and thus it was estimated to have the most significant positive impact on tyre life.

## Phase 2: Automate information

Phase 2 is associated with automated information regarding

certain aspects of tyre- and road-related elements. This step involves some capital cost and the associated increased operating costs. Phase 2 builds on Phase 1. The initiatives implemented in Phase 1 continue to be practised, with the additional changes described in Table V.

## Phase 3: Best Practise

Phase 3 is the culmination of the tyre management model. This phase involved the majority of the capital spend and has the highest additional operating cost. This step can be implemented only if Phase 1 and 2 were successful.

## Sensitivity analysis

By thoroughly analysing all the results, informed estimations of the cumulative effect of the various initiatives under each phase could be made. A sensitivity analysis was done to determine the impact of different scenarios for each step. These scenarios were classified as ‘worst case’, ‘most likely’, and ‘best case’. Each of these scenarios is characterized by a different impact of each step on:

- Reducing premature tyre failure (improvement method B)
- Reducing the site wear rate (improvement method A)

This is demonstrated by Table VI.

The results of the sensitivity analysis are shown in Figure 5 by displaying the calculated savings associated with each phase. Phase 1 has the largest positive impact on tyre life and results in the largest possible annual saving. Phases 2 and 3 have a smaller positive impact on tyre life, resulting in less annual saving. This is due to the fact that phases 2 and 3 involve fewer changes to the tyre management system. The better the tyre life on a mine becomes, the harder it is to improve it.

## Conclusion and recommendations

A tyre forum needs to be established at the mine. This forum should include representatives from various divisions of the mine. It is recommended that the tyre forum implement Phase 1 of the tyre management model. The most significant positive impact on tyre life is associated with Phase 1, with an increase in tyre life of 20% for the Komatsu 730 tyres and 75% for the CAT 777 tyres according to the ‘most likely’ scenario. Such an increase in tyre life will reduce the annual tyre usage and result in an annual saving of approximately R6 million.

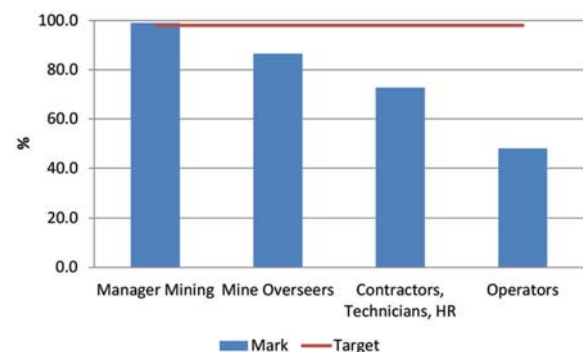


Figure 4—Level of tyre awareness among employees

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Table V  
**Tyre management model description**

Phase	Initiatives	Method		Description
		B	A	
1	Tyre awareness campaign			Based on similar tyre awareness campaign results at another mine. Cost based on one full-time employee salary to drive the programme
	Tyre life monitoring and feedback			Work with people, give information but also hold them accountable. Information is distributed using the current systems and discussed in the daily 09:00 production meeting and during the daily Operator Caucus sessions
	Operator education	✓		In house (no extra cost)
	Incentives			Exact incentive strategy will be designed by a tyre forum but will be based on individual truck tyre performance. This will single out and reward hard-working employees and will serve as extra motivation to take good care of tyres
	Payload control	✓	✓	Only CAT 777 trucks. Payloads will be manually monitored by operators with much more care
	Vehicle speed		✓	Vehicle speed will be manually monitored by all truck operators with much more care
	Pressure monitoring			
	Manual pressure checks (4 per day)	✓	✓	Increase the number of pressure checks to two per truck per shift. This will require two new employees.
	Road conditions			
	Site severity survey		✓	Reinstate the site severity survey as discussed previously. No extra cost
	Specialist grader operator training		✓	This requires the training of current grader operators by outside specialist to become specialist graders. R100 000 annual fee converted to a rand per month value. New training and refresher courses would be needed
	Supervisor application engineering training		✓	This entails the supervisors of grader operators to be trained by outside specialist in order to become experts in the field of grading (know what to look at in terms of grader performance, advice to give to operators, and how to apply the equipment to achieve the best result). R100 000 annual fee converted to a rands per month value. New training and refresher courses would be needed
Total impact	15%	0.1		
2	Road conditions			
	Permanent roads		✓	Implementation of the new monitoring system for main haul roads. Capital cost for units and operating cost for information processing
	Grader operator made higher level status		✓	Four specialist grader operators are appointed and a new career path is created with the total salary increased to match that of a haul truck operator. This will ensure that graders are operated only by grader specialists
	Pressure monitoring			
	iTrack for CAT 777 fleet	✓	✓	
	Vehicle speed		✓	iTrack TPMS installed for CAT 777 fleet. Operating cost includes two dedicated employees to monitor the system.
	TKPH monitoring	✓		
Total impact	2.5%	0.3		
3	Pressure Monitoring			
	iTrack for entire fleet	✓	✓	iTrack System for entire fleet. Free trial period is available. Operating cost includes three dedicated employees to monitored and drive the system. Capital cost includes the installation of system on the remaining 17 Komatsu 730 trucks
	Vehicle speed	✓	✓	
	TKPH monitoring	✓		
	Road conditions			
	Grader operator made increased	✓	✓	Six specialist graders operators are appointed and a new career path is created with the total salary higher level status to match that of a haul truck operator. This will ensure that graders are operated only by grader specialists
Total impact	2.5%	0.1		

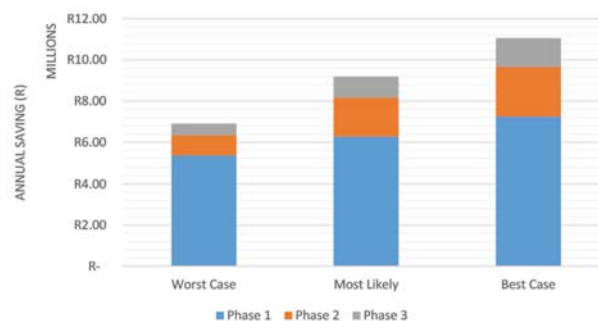


Figure 5—Possible annual saving for each scenario



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Table VI

### Sensitivity analysis estimations

Phase	Tyre life improvement method	Scenario		
		Worst case	Most likely	Best case
1	B	15%	20%	25%
	A	0.1	0.2	0.35
2	B	2.5%	5.0%	6.5%
	A	0.3	0.6	0.8
3	B	2.5%	5.0%	6.5%
	A	0.1	0.2	0.35

The main component of Phase 1 is the tyre awareness campaign. The exact details and specifications of this programme need to be designed and driven by the tyre forum to specifically suit the mine. Tyre life improvement needs to be a dynamic and ever-improving process.

Due to the capital sensitivity of the current mining environment, implementation of phases 2 and 3 is optional. The sensitivity analysis showed that the largest opportunity for savings lies with phase 1, which has virtually no extra cost associated with it.

It is the role of the tyre forum to conduct monthly meetings where the newly formulated tyre management model is discussed and evaluated, focusing on four major areas:

- Conditions
- Operations
- Maintenance
- Tyre performance.

### Acknowledgement

This paper is based on project work carried out in partial fulfilment of the degree B Eng (Mining Engineering)

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