Technical Report

# EFFECT

# OF

# PROPORTION OF NEW TYRE FITMENTS BY AXLE

# UPON

# HAULTRUCK TYRE LIFE AND DOWNTIME

# 1 Introduction

Tyres, and downtime due to tyre changes, account for a significant proportion of the cost of operating haultrucks in open pit mines. Tyre related costs can be reduced by increasing tyre life – accomplished through proper tyre selection and servicing, haulroad design and maintenance, and operator practices.

A belief held by some maintenance and production managers in the mining industry is that haultruck tyre life can *also* be improved by ensuring that no new tyres are fitted to the rear axle. This is not the case; such a policy will in fact increase total cost (refer Figure 1) because it has:

1. no significant effect upon haultruck overall tyre life, but
2. a considerable detrimental effect on haultruck downtime.

Otraco recommends against a tyre fitment policy which prescribes that no new haultruck tyres may be fitted to the rear axle.1

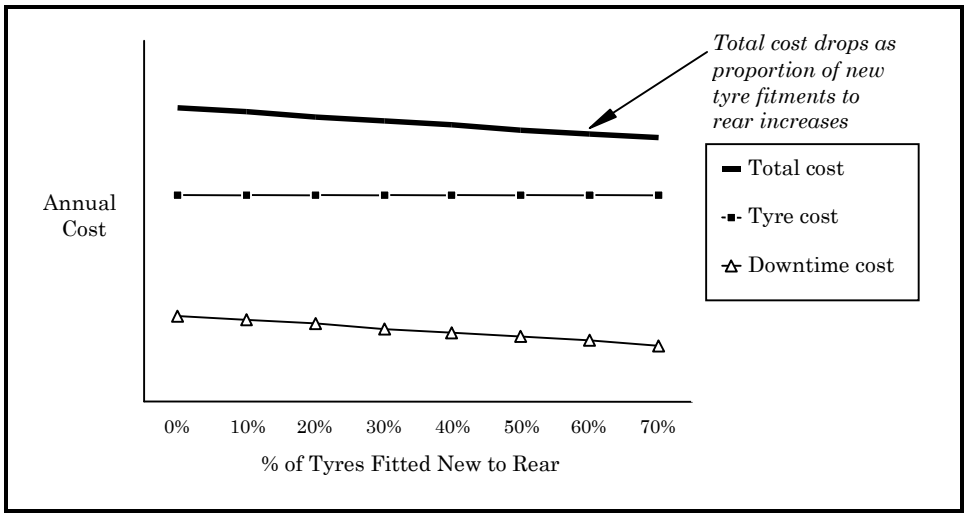


**Figure 1 – Effect of the proportion of new tyre fitment by axle on tyre related costs**

## Notes

The analysis that follows establishes the relationships shown in Figure 1; three important points apply.

1. *Overall* tyre life is the key parameter, i.e. the (unbiased) average life for *all tyres* fitted to, and run on a haultruck fleet *over an extended period*.[2]
2. All references to life denote *average*[3] life – not life for individual tyres.

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[1] This recommendation does not conflict with the safety policy adopted by the majority of minesites of fitting *only* new tyres (i.e. no runouts) to the front axle of haultrucks.

[2] Variations in new tyre fitment by axle can affect:

i. the life of one batch of tyres, at the expense of other batches fitted during the same period,
ii. the life of tyres fitted in one period, at the expense of those tyres fitted in the following period.

However, variations in new tyre fitment by axle do not affect *overall* tyre life.
(Fitment bias analysis was developed by Otraco in 1979 specifically to adjust for axle fitment bias in individual batches of tyres.)

3. The factors that determine overall tyre life – tyre selection, servicing, haulroad care and operator practices – are assumed to remain constant. Only the the proportion of new tyre fitment by axle is regarded as being variable, so that the effect of changes in this variable can be investigated.

A Glossary appears in Appendix I.

The belief that no new tyres should be fitted to the rear axle of haultrucks commonly originates on hard rock mines running rear dump trucks where rear tyre life is generally lower than front tyre life.

Factors which cause this include:

1. Operating conditions – e.g. rock damage, haul gradients
2. Truck characteristics – e.g. weight distribution, axle configuration.

Rock damage is usually the most significant cause of life variation between front and rear tyres.

1. Truck drivers can relatively easily avoid running over spillage with their front tyres; it is more difficult to avoid similar damage to rear tyres.
2. When haultrucks reverse under loaders or up to tip points, the rear tyres bear the brunt of the rock damage associated with these operations.

[3] For example, *average* front tyre life, *average* rear tyre life, *average* ROR life, etc.

## 2 Common argument for fitment policy

On hard rock mines, the policy of fitting every new tyre to the front axle of rear dump haultrucks (and running them on this axle for as long as possible) does, on the face of it, appear to have merit for maximising tyre life.

The argument typically advanced in support of this policy is as follows:

- tyres are more likely to fail prematurely on the rear axle (due to rock damage)
- it is preferable to lose well worn tyres due to premature failure rather than near new tyres
- hence it must be better to fit every new tyre to the front and only (well worn) runout tyres to the rear.

### *2.1 Problems with above argument*

The problem with the above reasoning for fitting every new tyre to the front is that it overlooks the fact that a trade-off is involved. This trade-off is:

> *As the proportion of new tyres fitted to the front axle increases, front tyres have to be replaced at an ever lower average life (so that they can be run out on the rear axle).*

The effect that this trade-off has on tyre life is as follows:

- the proportion of new tyre fitment by axle affects the average life at which front tyres must be removed for run out on the rear
- the average life at which front tyres are removed for run out on the rear affects, in turn, the final average life of these same tyres.

In an application where front tyre life is higher than rear tyre life one may *attempt* to improve overall tyre life by either:

1. fitting a greater proportion of new tyres to the front to reduce their exposure to low life rock damage, or
2. running those tyres fitted new to the front for as long as possible on that axle before running them out on the rear where the risk of rock damage is higher.

Unfortunately, the above two 'remedies' are mutually exclusive. Invoking either one produces an automatic negative effect on the other. The more tyres that are fitted new to the front, the lower the final average life of these tyres because they have to be removed from the front earlier to be run out on the rear. Overall tyre life, however, remains unaffected.

### *2.2 Non-adherence to fitment policy*

Very few minesites follow a policy of fitting every new haultruck tyre to the front axle. Most reject it because of the greater number of tyre changes – and hence haultruck downtime – that goes hand in hand with such a policy (discussed in

more detail below). Otraco, whose primary objective is to minimise tyre associated costs for our client companies, does not embrace the policy.

There are some circumstances where manipulation of haultruck new tyre fitment may be justified[4], however these cases are rare in rear dump truck/hard rock mining applications and are outside the scope of this study.

### *2.3 Justification for waiving fitment policy*

There are two main reasons for not following a specific fitment policy.

Fitting no new tyres to the rear –

i. has no measurable effect on overall tyre life

ii. can significantly increase haultruck downtime.

[4] For example on some high speed long haulage operations using prime-mover/trailer configurations, radial tyres are run briefly on the drive axle in order to 'torque-set' them prior to fitting them to the steer or trailer axles – thus minimising abnormal tread wear patterns.

## 3 New tyre fitment policy – effect on overall tyre life

Figure 2 shows the relationship (for two-axle, six-tyred trucks) between new tyre fitment by axle and average life at which front tyres must be removed for run out on the rear (ROR).

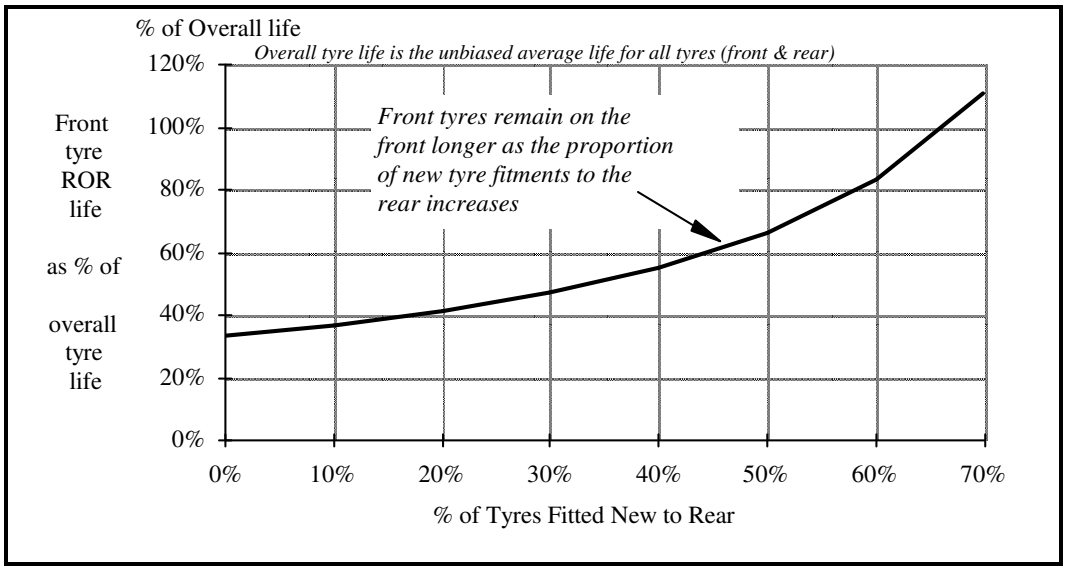



**Figure 2 – Effect of the proportion of new tyre fitment by axle on average ROR life for front tyres**

The relationship shown in Figure 2 can be expressed as the following equation[5]; its derivation appears in Appendix II.

Av. ROR life = Overall tyre life ÷ (3 x Proportion of new tyre fitment to front axle)

***Example***

Assume that a fitment policy is strictly enforced on a minesite whereby every new haultruck tyre is fitted to the front axle. These tyres would on average have to be removed from the front when they have run only *one-third* of haultruck overall tyre life (refer Figure 2). Unless this is done there would be insufficient runout tyres to satisfy the requirement for rear fitment tyres, and some trucks in the fleet would have to be stood down.

If the fitment policy is subsequently relaxed with the result that perhaps only 50% of all new tyres are now being fitted to haultruck front positions, then these tyres will not have to be removed from the front until they have run, on average, *two-thirds* of haultruck overall tyre life.

The relaxation of policy has led to only half the number of new tyres being fitted to the front axle; however these tyres will spend, on average, twice as long on this axle before being changed to the rear axle – that is the trade-off.

[5] This equation assumes that tyres fitted new to the rear are not subsequently refitted to a front position (generally the case for most rear fitment tyres on the majority of minesites); the assumption greatly simplifies the analysis presented in this article.

### 3.1 Tyre life model

In order to quantify the effects of new tyre fitment by axle on overall tyre life it is necessary to develop a tyre life model.

Otraco has eight tyre service operations around Australia covering a wide range of operating conditions, and access to a large database of tyre life history. Analysis of this data, along with our tyre servicing experience, has enabled us to produce a simple but realistic tyre life model.

The elements of this model[6] are as follows:

- The model represents the average overall behaviour of a large group of tyres (not individual tyres) operating under conditions of zero axle fitment bias.
- The parameters which determine tyre life – tyre specifications, tyre maintenance, haulroad care and operator practices – are assumed to remain unchanged.
- The proportion of new tyre fitment by axle (front or rear) is variable.
- Tyres fitted new to the front are subsequently removed for run out on rear.
- Tyres fitted to the rear are not refitted to front positions.
- Average life of tyres fitted new to the rear is unaffected by the proportion of new tyre fitment by axle.
- Average life of tyres fitted new to the front is dependent on the average life at which these tyres are removed for run out on the rear (ROR), approximated as a linear[7] relationship where:
  - magnitude of slope represents magnitude of tyre life variation by axle
  - as average ROR life of tyres fitted new to the front approaches nil, the average life of these tyres approaches that of tyres fitted new to the rear.

A full mathematical description of the model is contained in Appendix III.

The model is depicted graphically in Figures 3 and 4 – showing tyre life by axle (which for front tyres depends on the life at which they are run out on the rear) and overall tyre life, respectively. This case represents an application where front tyre life is considerably higher than rear tyre life (refer Table 1 of Appendix III for data). The two other scenarios (where front life is less than rear life, and where it equals rear life) are shown in Appendix IV.

[6] The model applies to two-axle six-tyred rear dump trucks. Similar but more complex models could be developed for three-axle six-tyred and three-axle ten-tyred units as well.
[7] Based on the analysis of data for many large batches of tyres.

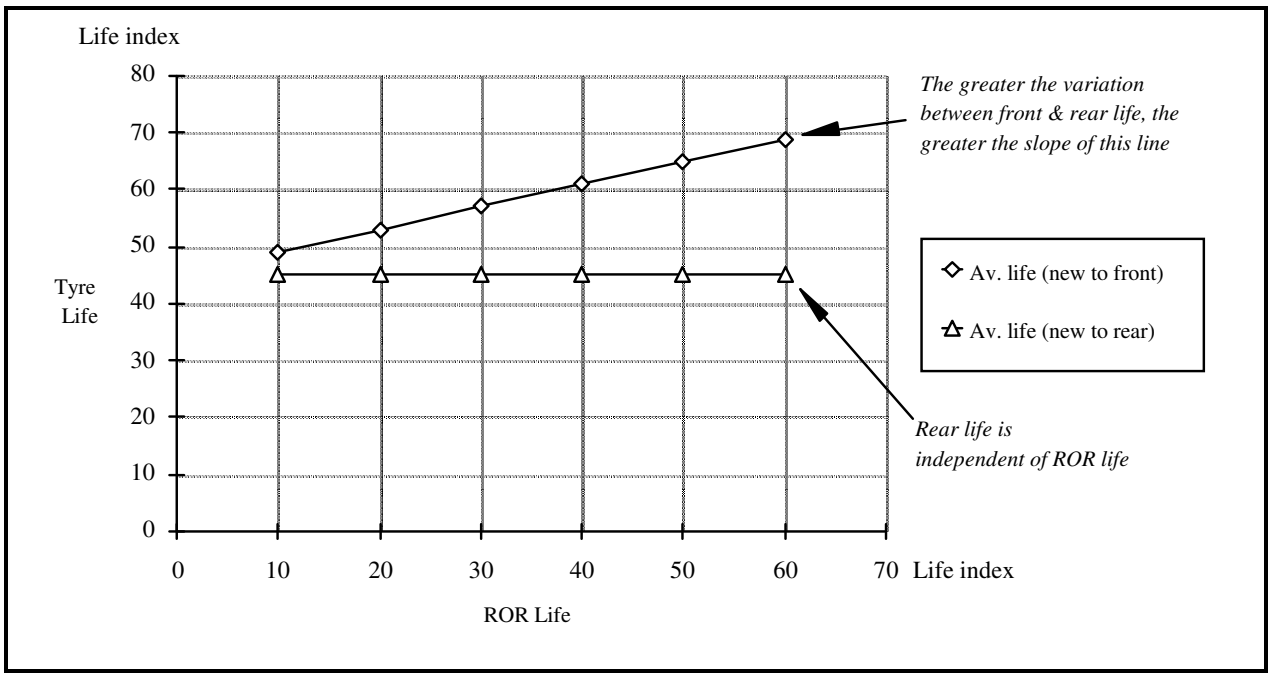



**Figure 3– Effect of average ROR life on final average life for tyres fitted new to front**

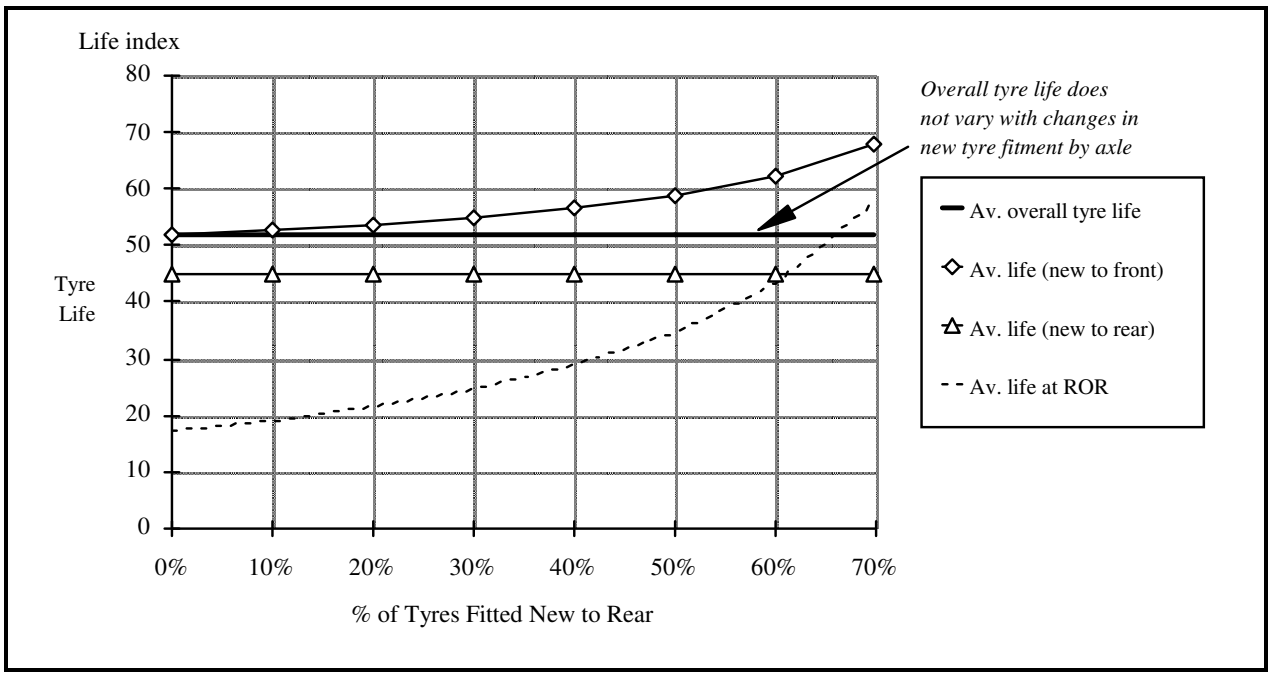



**Figure 4 – Effect of the proportion of new tyre fitment by axle on average tyre life**

The model demonstrates that *haultruck overall tyre life is independent of the proportion of new tyre fitment by axle.*

This is true, irrespective of whether the average life of tyres fitted new to the front is higher, equal to, or lower than the average life of tyres fitted new to the rear.

***Example***

Take a minesite where haultruck front and rear tyre life is as depicted in Figure 3. Tyre life figures are expressed in terms of a tyre life index (for this example let 10 represent 10,000 km). Assume a fitment policy whereby every new haultruck tyre is fitted to the front axle (and no rear tyres are refitted to the front). From Figure 4, these front tyres would have to be removed for run out on the rear at an average life of 17,000 km – 33% of haultruck overall tyre life (refer Figure 2). When front tyres are on average being run out on the rear at 17,000 km, their final life will average 52,000 km (refer Figure 3). Because no tyres have been fitted new to the rear, haultruck overall tyre life will be equivalent to that of tyres fitted new to the front, i.e. 52,000 km.

Assume fitment policy is relaxed so that now, say, only 50% of new tyres are fitted to the front. From Figure 4, the front tyres would now be run on average through to 35,000 km (67% of haultruck average tyre life) before being removed for run out on the rear (ROR). At this average ROR life, the final average life for front tyres would be 59,000 km (refer Figure 3), while the average life of the 50% of tyres fitted new to the rear remains constant at 45,000 km. Haultruck overall tyre life, which is the weighted average of front life (59,000 km) and rear life (45,000 km), remains unchanged – 52,000 km.

The relaxation of fitment policy has resulted in less tyres being fitted new to the front, but these tyres are now averaging higher life because they are able to run longer on the front before being removed to be run out on the rear. However, *the change in fitment policy has not changed overall tyre life.*

# 4 New tyre fitment policy – effect on haultruck downtime

Tyre change levels are certainly influenced by the proportion of new tyre fitment by axle. As a consequence haultruck downtime levels are almost always affected as well.

Most minesites have a policy that haultruck front tyre failures should be avoided (mainly for safety considerations). As a result front tyres are removed for run out on the rear prior to their becoming too worn. Almost every front tyre will therefore be fitted at least twice during its life – once as a new tyre to the front and once as a runout tyre to the rear. Additional changes may subsequently be required because of matching or other considerations.

Rear tyres on most minesites are rarely refitted to front positions. Hence a tyre fitted new to the rear axle will have only that one fitment during its life unless it has to be changed at some stage for matching purposes or the like.

In general, every tyre fitted new to the front has at least two fitments during its life, and every tyre fitted new to the rear at least one fitment.

## *4.1 Tyre change index*

A tyre change index can be used to quantify the effects of the proportion of new tyre fitment by axle upon the total number of haultruck tyre changes and downtime. The tyre change index is a measure of the minimum number of tyre changes required in a particular application (excluding changes for matching or other similar reasons).

The relationship between the tyre change index and the proportion of new tyre fitment by axle is as follows:

Tyre change index = Proportion of new tyre fitment to front axle + 1

This equation is presented graphically in Figure 5; its derivation appears in Appendix III.

***Example***

A minesite that enforces a policy of no new tyre fitments to the rear will have a tyre change index of 2 (refer Figure 5).

On minesites where there is no specific policy on new tyre fitment by axle and where front tyres are removed when they are around half worn (for run out on the rear), the natural order generally results in approximately 50% of new tyres being fitted to the rear axle. Under these circumstances the tyre change index will be 1.5.

This means that, for any application, the number of tyre changes – and hence haultruck downtime – will be around *30% higher* if every new tyre is fitted to the front (compared with a situation where no such policy exists).

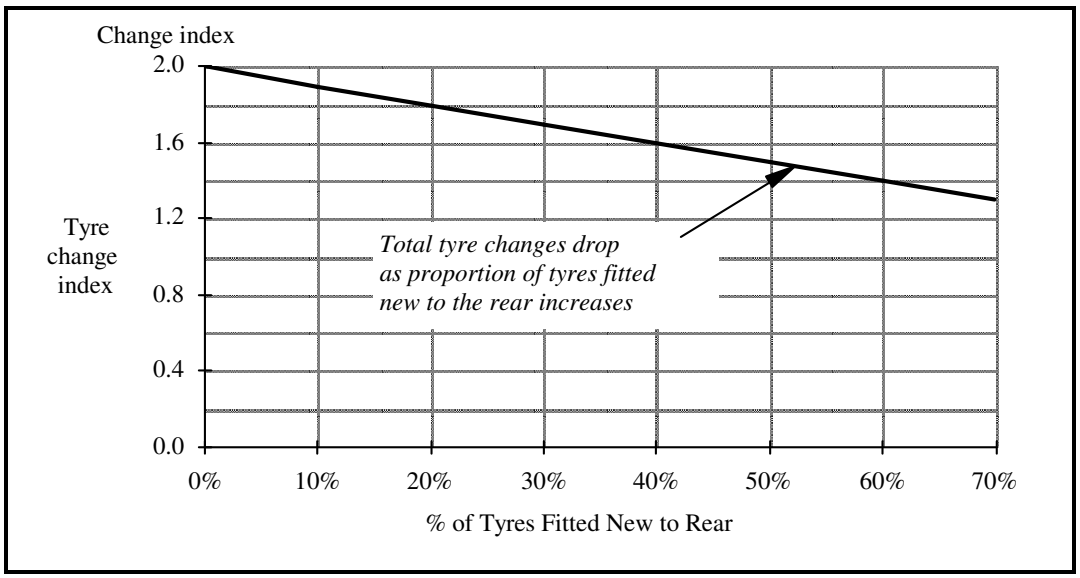



**Figure 5 – Effect of the proportion of new tyre fitment by axle on tyre changes and downtime**

# 5 Conclusions & Recommendations

## *5.1 Conclusions*

For most minesites operating rear dump haultrucks there is no benefit to be gained by fitting every new tyre to the front axle. Overall tyre life is unaffected by the proportion of new tyres fitted to each axle.

However the proportion of new tyre fitment by axle has a significant effect upon total haultruck tyre changes and downtime – the greater the proportion of new front fitments, the more truck downtime will be incurred.

The analysis in this article has been confined to two-axle six-tyred trucks (which comprise the vast majority of trucks on hard rock mines), and assumes that rear tyres are not refitted to the front.

A tyre life model could be developed for applications where rear tyres are refitted to the front; it would be more complex requiring a series of graphs for variations in life spent by rear fitment tyres on the front. Similarly, tyre life models could be developed for other axle/tyre configurations.

We believe that these models would show the same general results – that the proportion of tyre fitment by axle affects truck total tyre changes, but not overall tyre life.

### 5.1.1 Comparison with the real world

The predictions by the tyre life model reflect what Otraco has analysed and observed in the field over many years.

a) New tyre fitments can be manipulated to increase the life of one batch of tyres, but only at the expense of other batches in the same application. Overall life for the application remains unaffected.

b) Tyre change and downtime levels do increase with the proportion of new tyre fitments to the front.

## *5.2 Recommendations*

- Otraco advises against a tyre fitment policy which prescribes that no new tyre should be fitted to the rear axle of a haultruck.

- This recommendation does not conflict with the safety policy adopted by the majority of minesites of fitting only new tyres (i.e. no runout tyres) to the front axle of haultrucks.

# 6 Appendix I – Glossary

| Term | Definition |
|---|---|
| Batch | Tyres grouped by period of original (new) fitment (as opposed to period of scrap). |
| Overall tyre life | True or unbiased average tyre life.<br><br>It is the average life for a large number of tyres fitted to and run on a truck fleet over a long period of time. |
| Unbiased average life | See *Overall tyre life* |
| Axle fitment bias | The result of a *batch* of tyres not being equally exposed (in proportion to the number of tyres per axle) to the hazards and conditions of each axle.<br><br>For a batch of tyres, the condition of zero axle fitment bias is satisfied if the ratio of total life run on each axle equals the ratio of wheels on each axle. |
| Runout tyre | A tyre awaiting fitment, which has had at least one previous fitment. |
| ROR | Run out on the rear.<br><br>Fitting and running a *runout tyre* (which has been removed from the front axle) on the rear axle.<br><br>Front tyres are generally removed for run out on the rear prior to their becoming too worn, or if they receive an injury. This is a safety precaution to minimise front tyre failures (which are more likely to cause accidents than rear tyre failures). |
| ROR life | Life, or average life, at which a tyre or tyres are removed from the front axle to be run out on the rear axle. |
| Life index | A general measure of tyre life.<br><br>e.g. a life index of 10 could represent 1,000 hours. In this case a *ROR life* of 20 would mean a tyre or tyres removed for run out on the rear at 2,000 hours; tyre life of 50 would represent tyre life of 5,000 hours. |
| Tyre change index | The minimum number of tyre changes that a tyre undergoes during its life.<br><br>e.g. tyres fitted new to the front axle generally have a tyre change index of 2 because they are subsequently run out on the rear, i.e. each front tyre generally undergoes a minimum two changes during its life. |

# 7 Appendix II – Derivation of Equation

Equation linking the Percentage of Overall Life at which Front Tyres are Run Out on Rear (ROR) & the Proportion of New Tyre Fitment by Axle

**To prove:**

*Av. ROR life* [8] *= Overall tyre life ÷ (3 x Proportion of new tyre fitment to front axle)*

Derivation:
Overall tyre life is the unbiased average life of all tyres run in the application. The condition for unbiased tyre fitment by axle is satisfied if the ratio of total life run on each axle equals the ratio of wheels on each axle. For a fleet of two-axle six-tyred trucks this condition is as follows:

*Total tyre life run on rear wheels is twice total tyre life run on front wheels.*

Equation 1 is the general equation that satisfies the condition of unbiased axle fitment[9] for two-axle six-tyred trucks.

$$(B \times X) + (D \times Y) = 2 \times ((A \times X) + (C \times Y)) \quad 1.$$

*where* $X$ = *Proportion of new tyre fitment to Front axle*
$Y$ = *Proportion of new tyre fitment to Rear axle*
$A$ = *Av. life that new Front fitment tyres run on the Front axle*
$B$ = *Av. life that new Front fitment tyres run on the Rear axle*
$C$ = *Av. life that new Rear fitment tyres run on the Front axle*
$D$ = *Av. life that new Rear fitment tyres run on the Rear axle*

*Note:* ***A = Av. ROR life*** *( i.e. Av. life at which front tyres are removed for run out on rear)*

Equation 2 is the expression for average tyre life (Lt) which, if the conditions represented in equation 1 are fulfilled, is unbiased average tyre life or **overall tyre life**.

$$Lt = ((A + B) \times X) + ((C + D) \times Y) \quad 2.$$

Equation 1 can be reduced to equation 3.

$$(D \times Y) - (2 \times C \times Y) = (2 \times A \times X) - (B \times X)$$

$$Y = \frac{X \times ((2 \times A) - B)}{D - (2 \times C)} \quad 3.$$

Substituting the expression for Y from equation 3 into equation 2 gives:

$$Lt = ((A + B) \times X) + \frac{X \times ((2 \times A) - B) \times (C + D)}{D - (2 \times C)}$$

$$Lt = X \times \frac{(A + B) \times (D - (2 \times C)) + ((2 \times A) - B) \times (C + D)}{D - (2 \times C)}$$

$$Lt = \frac{3 \times X \times ((A \times D) - (B \times C))}{D - (2 \times C)} \quad 4.$$

[8] This equation applies to two-axle six-tyred trucks only, and assumes that no rear tyres are fitted to the front axle.

[9] While an individual batch of tyres may exhibit significant axle fitment bias, bias will approach zero when considering all tyres fitted over a substantial period.

Equation 4 can be greatly simplified (facilitating analysis of the tyre life model) if the following constraint, which applies for the majority of rear fitment tyres on most minesites, is imposed:

*Constraint: no rear tyres are refitted to the front axle, i.e. C = 0*

$$Lt = 3 \times A \times X$$

$$A = Lt \div (3 \times X)$$

$$\text{Av. ROR life} = \text{Overall tyre life} \div (3 \times \text{Proportion of new tyre fitment to front})$$

# 8 Appendix III – Mathematical Description

And Sample Calculation of Tyre Life Model[10]

**A. Relationship between new tyre fitment by axle & truck overall tyre life**

The tyre life model used to study the relationship between haultruck overall tyre life and the proportion of new tyre fitment by axle is defined by equations 5 and 6.

Av. life of tyres fitted new to rear (Lr) = Constant *(dependent on site conditions)* 5.

Av. life of tyres fitted new to front (Lf) = Lr + (S x A) 6.

*where S* = *Slope (a constant, dependent on magnitude of variation between front & rear tyre life, S > 0 if Lf > Lr; S < 0 if Lf < Lr)*

Equation 5 states, in the context of the tyre life model, that average life for tyres fitted new to the rear does not alter with variations in new tyre fitment by axle.

Equation 6 states that as the life at which front tyres are removed for run out on the rear (ROR) approaches zero, the average life for these tyres approaches that of tyres fitted new to the rear.

Equation 7 describes the relationship among haultruck overall tyre life (i.e. unbiased average tyre life), the life at which front tyres are run out on the rear (ROR), and the proportion of new tyre fitment by axle[11] (refer Appendix II for derivation).

Av. ROR life (A) = Lt ÷ (3 x X) 7.

*where Lt* = *Haultruck overall tyre life*

*X* = *Proportion of new tyre fitment to front axle*

Equation 8 is the standard calculation for haultruck overall tyre life.

Haultruck overall tyre life (Lt) = (X x Lf) + (Y x Lr) 8.

*where Y* = *Proportion of new tyre fitment to rear axle*

Substituting the expressions for Lf from equation 6 and A from equation 7 into equation 8 gives:

$$Lt = X \times \left(Lr + \frac{S \times Lt}{3 \times X}\right) + (Y \times Lr) \quad 9.$$

$$Y = 1 - X \quad 10.$$

Substituting the expression for Y from equation 10 into equation 9 gives:

$$Lt = X \times \left(Lr + \frac{S \times Lt}{3 \times X}\right) + ((1-X) \times Lr)$$

$$= (X \times Lr) + \frac{S \times Lt}{3} + Lr - (X \times Lr)$$

$$= \frac{S \times Lt}{3} + Lr$$

$$Lt = \frac{Lr}{\left(1 - \frac{S}{3}\right)} \quad 11.$$

From equations 5 and 6, Lr and S are constants which are dependant on site conditions, hence:

Lt = constant

*i.e. Overall tyre life is independent of the proportion of new tyre fitment by axle.*

[10] This model applies to two-axle six-tyred trucks only.

[11] Equation 7 assumes that rear tyres are not refitted to the front axle.

**B. Relationship between new tyre fitment by axle & truck tyre changes**

The *tyre change index* is defined as the minimum total number of tyre changes (excluding changes for matching purposes, etc.) per new tyre fitment.

The minimum number of tyre changes per tyre fitted new to each axle (refer main article for explanation) is as follows:

Minimum no. of tyre changes for tyres fitted new to front = 2
Minimum no. of tyre changes for tyres fitted new to rear = 1

$$\text{Tyre change index (Ci)} = (X \times 2) + (Y \times 1) \qquad 12.$$

Substituting the expression for Y from equation 10 into equation 12 gives:

$$Ci = X + 1$$

$$\text{Tyre change index} = \text{Proportion of new tyre fitment to front} + 1$$

**C. Sample calculation using tyre life model**

Results for a sample calculation of the tyre life model are shown in Table 1. Parameter values would normally be based on values applicable to the particular application; the values selected for this example (noted below) are those used for Figures 3 and 4 of the main article.

Values for the parameters Lr and S, applicable to Table 1, are:

Lr = 45 (index of average life for tyres fitted new to rear)
S = 0.4 (measure of variation between tyre life by axle)

Substituting these values into equation 11 gives:

$$Lt = \frac{45}{(1 - \frac{0.4}{3})}$$

$$= 51.92$$

Hence for the example mentioned, overall tyre life remains constant at a tyre life index of 51.92, rounded to 52 in Table 1 below.

| X | 100 % | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% | 10% | 0% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y=1-X | 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100 % |
| Lr | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| A as % of Lt | 33% | 37% | 42% | 48% | 56% | 67% | 83% | 111 % | * | * | * |
| A=Lt/3X | 17 | 19 | 22 | 25 | 29 | 35 | 43 | 58 | * | * | * |
| Lf=Lr+(S.A) | 52 | 53 | 54 | 55 | 57 | 59 | 62 | 68 | * | * | * |
| Lt=(X.Lf)+(Y.Lr) | **52** | **52** | **52** | **52** | **52** | **52** | **52** | **52** | * | * | * |
| Ci=X+1 | **2** | **1.9** | **1.8** | **1.7** | **1.6** | **1.5** | **1.4** | **1.3** | * | * | * |

* *The specified level of new tyre fitment to the front (X) would result in an unsustainable situation. The need for front tyres could not be satisfied; trucks would have to be stood down.*

**Table 1 – Sample tyre life model calculation results**

Notes applicable to Table 1:

1. The life figures used in the sample calculation are expressed in terms of a tyre life index (e.g. 1 could represent 1,000 km).

Examples and comments:

1. If a minesite has a strictly enforced policy that no new tyres are to be fitted to the rear then the average life at which front tyres will, over the long term, have to be removed from front positions for run out on rear (A) will be 33% of haultruck overall tyre life.

   It would be impossible in the long term to defer average ROR life past this average 33% life, because if one attempted to do so insufficient runout tyres would be generated for fitment to rear positions and hence some trucks would have to be stood down.

   Alternatively, under this fitment policy if fronts were removed on average before they reached 33% of average life then a surplus of runouts would be generated (too many for them all to be used on the rear).

2. Restricting new tyre fitment to the front to less than a certain level would not be feasible, e.g. for front tyre fitment (X) to be maintained at less than 30% would require these tyres to stay on this axle until they had run more than 111% of haultruck av. tyre life (Lt).

3. Overall life (Lt) remains unchanged while the tyre change index (Ci) changes with variations in the proportion of new tyre fitment by axle (X).

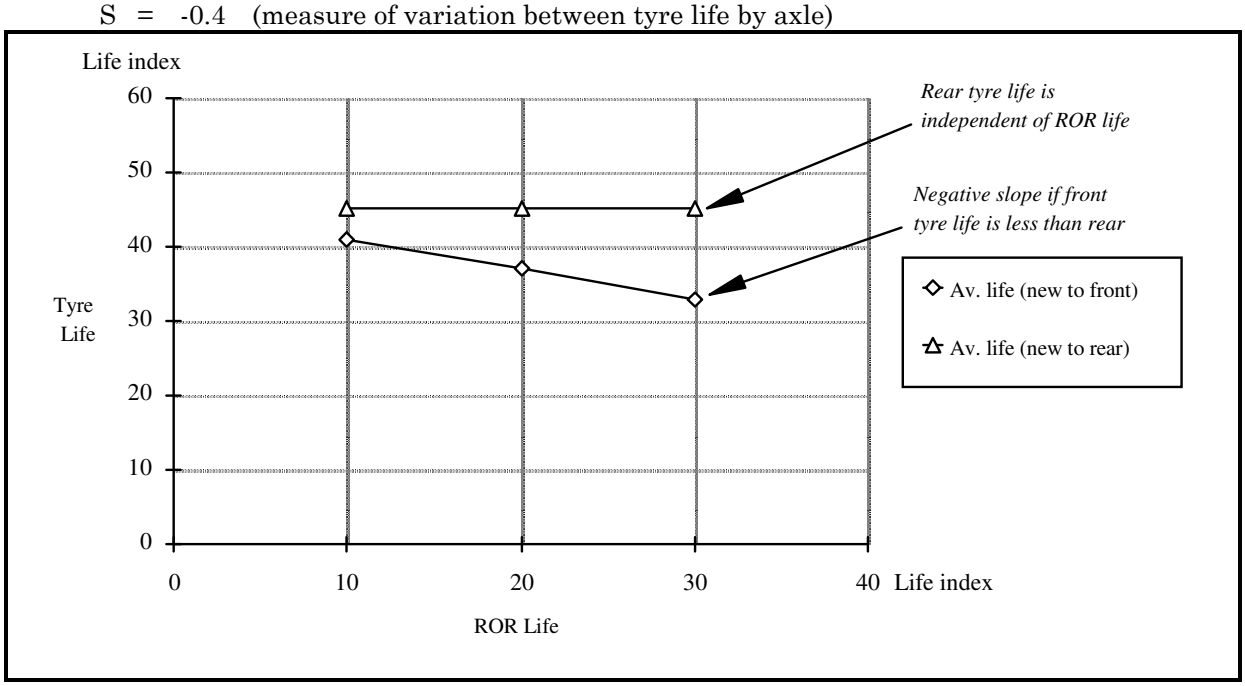
# 9 Appendix IV – Effect of Variations

In Tyre Life by Axle upon Tyre Life Model *(compare with Figures 3 & 4 of main article)*

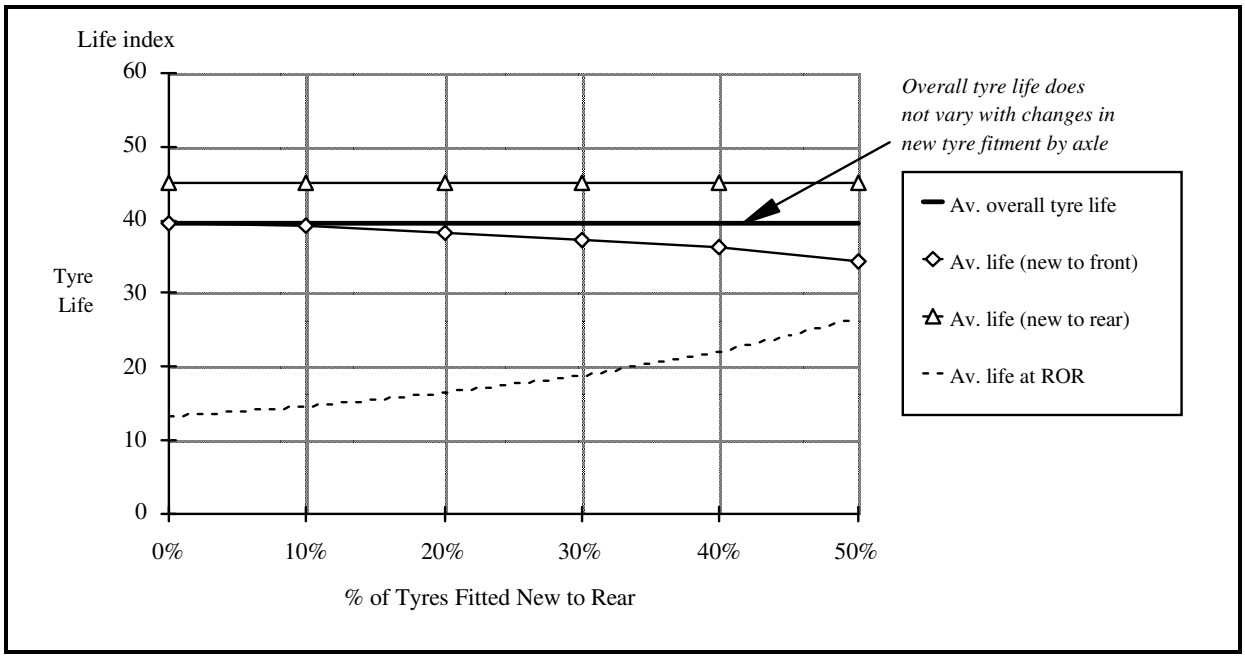
## Condition 1 – *Rear axle tyre life is **greater** than Front axle tyre life*

Values for the parameters Lr and S, applicable to Graphs 1 and 2 are:

Lr = 45 (index of average life for tyres fitted new to rear)
S = -0.4 (measure of variation between tyre life by axle)




**Graph 1– Effect of average ROR life on final average life for tyres fitted new to front**

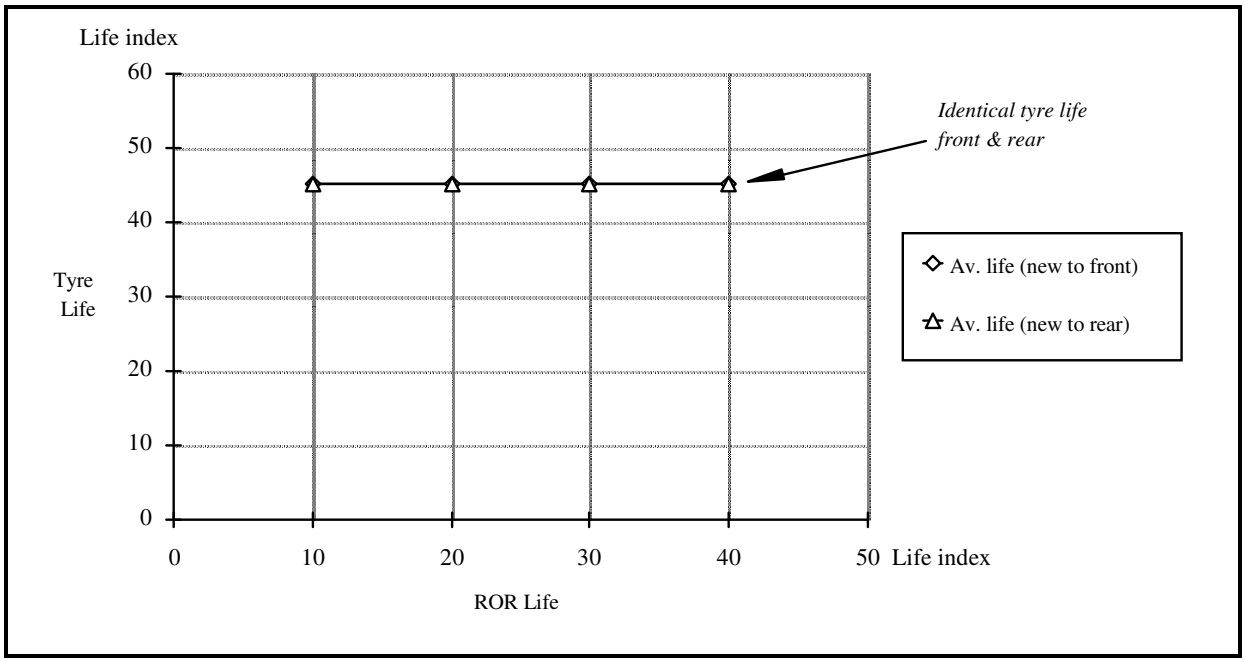



**Graph 2 – Effect of the proportion of new tyre fitment by axle on average tyre life**

## Condition 2 – *Rear axle tyre life is **equal** to Front axle tyre life*

Values for the parameters Lr and S, applicable to Graphs 3 and 4 are:

Lr = 45 (index of average life for tyres fitted new to rear)
S = 0 (measure of variation between tyre life by axle)




**Graph 3– Effect of average ROR life on final average life for tyres fitted new to front**