Mining Tyre Solutions

Factoring Tyres into Autonomous Haulage in Surface Mines

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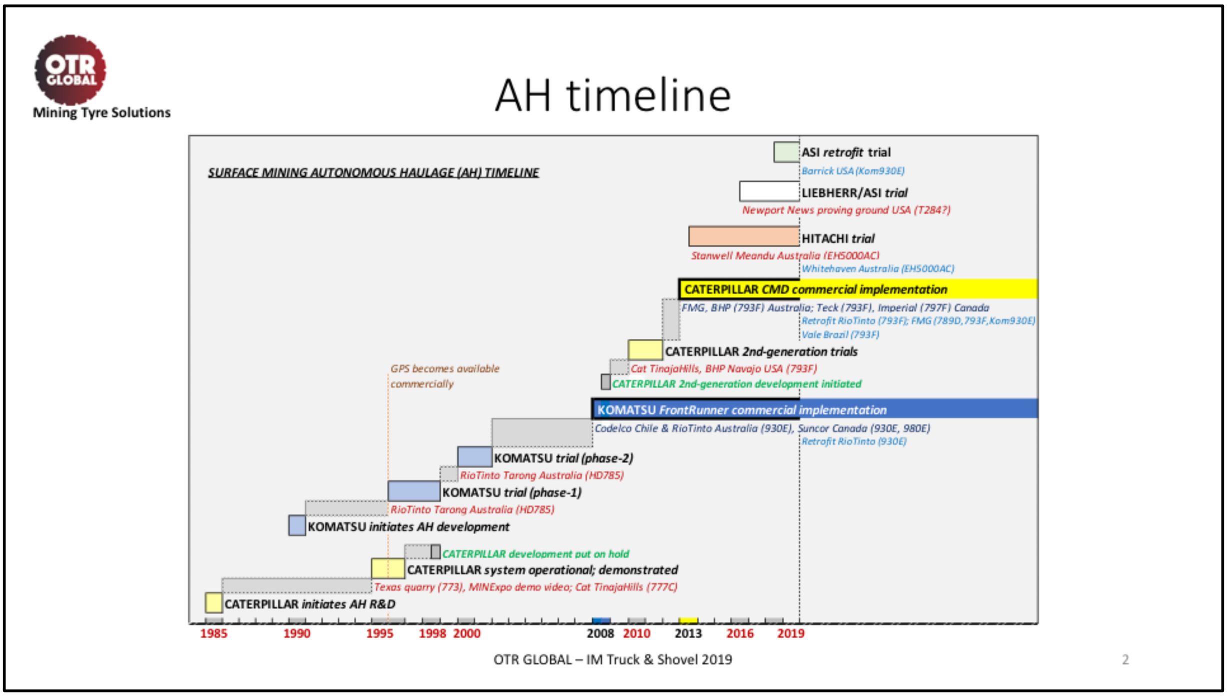
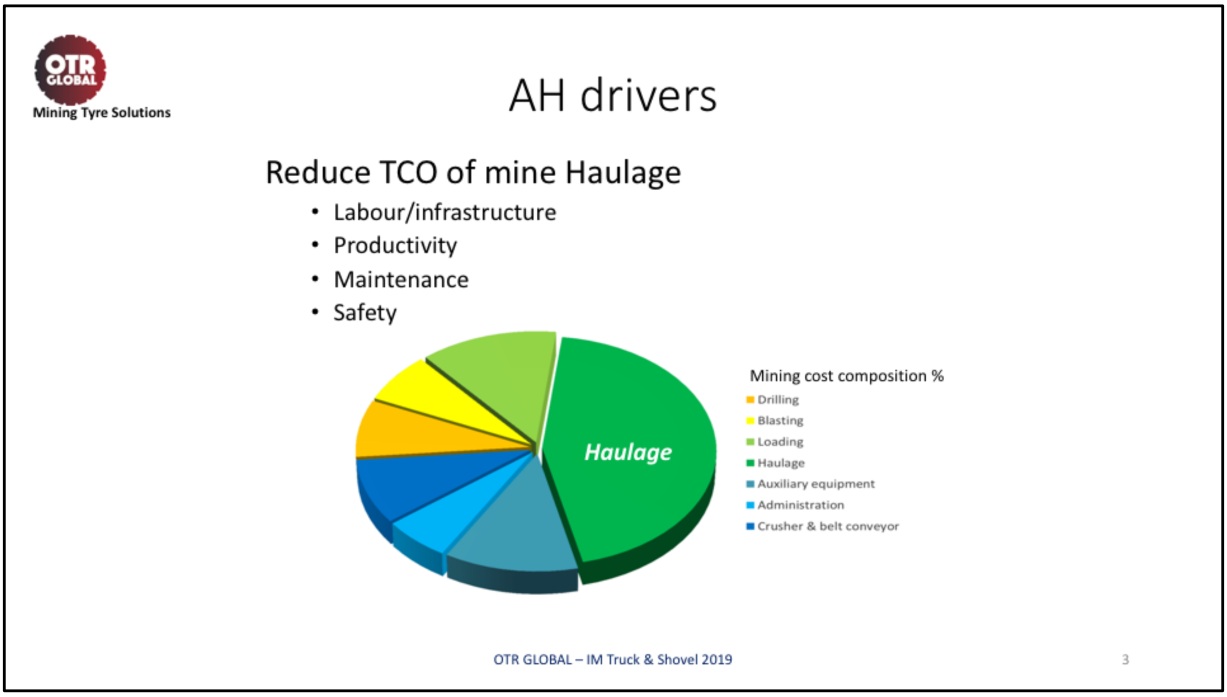


- Autonomous haul trucks 1st mooted **40 years ago** (late 70s/early 80s).
- **Caterpillar** started development in **1985** leading to the 1st AHT (Cat773) at Texas quarry in **1995** but then put program on hold in **1998**
- **Komatsu** was testing its 1st AHTs (Kom HD785s?) at Qld mine in **late 90s.** They made the 1st commercial deployment (930Es) in **2008** at Codelco Gaby in Chile, followed by RTIO West Angelas in the Pilbara.
- **Cat's** initial commercial deployments: 793Fs in **2013** at FMG Solomon & BHP Jimblebar.
- **Hitachi** was the 3rd OEM to develop an in-house AHS – testing from 2013 on EH5000s at Meandu Coal (Stanwell Corp).
- The other main two AHS developers provide agnostic systems that work on any brand of HT.
    - **ASI** (USA) working with Liebherr and also Barrick (930s)
    - **Zyfra/VIST** (Fin/Russian) working with Belaz (7513R).

➢ ***The adoption of AH is exploding at present including many well-established operations converting to it.***

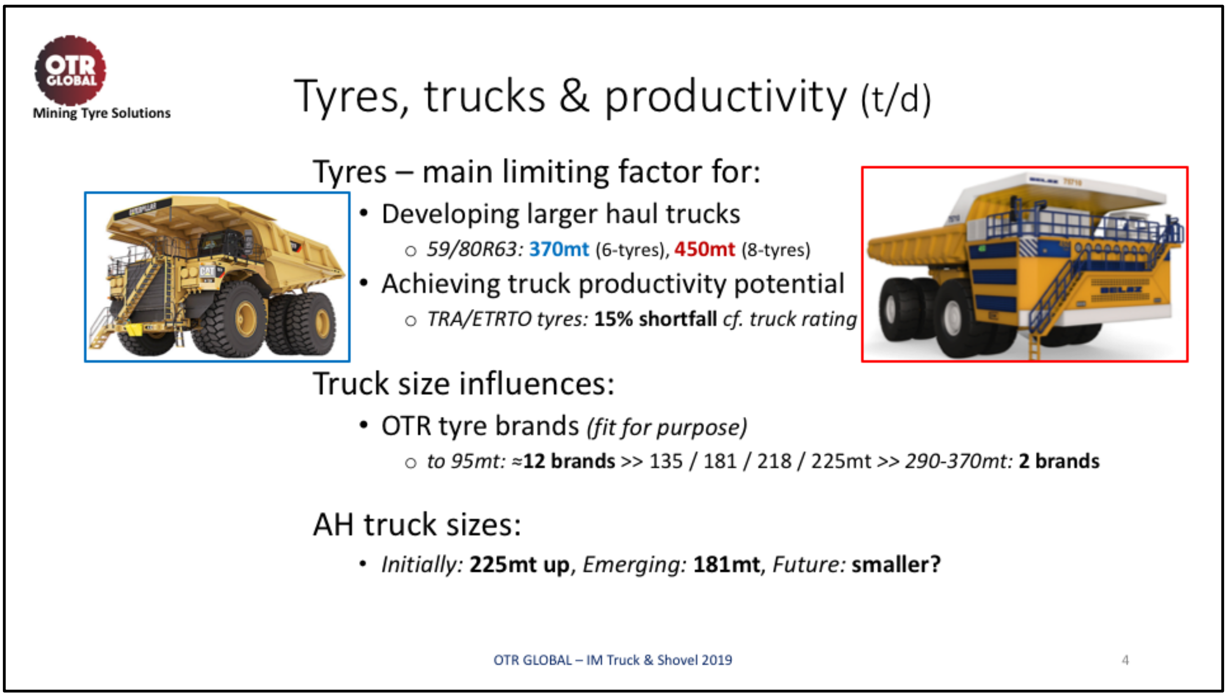


Haulage comprises a large chunk of total **mining cost** & is a major determinant of **mine productivity**.

AH provides the means to make a **significant improvement to both**.

The **drivers** for AH are:

- **Manning reduction**
  - Direct labour *(3.5-4.5 > 0.8 employees/truck)*
  - Support services *(airfares, board, catering)*
  - Support infrastructure *(housing/facilities)*
- **Productivity increase** *(tonnes per shift)* – usually the ***main*** driver
  - No operator breaks *(shift change, meal & rest – 2-2.5h/d , approach 1,000h/yr*
  - Operational consistency *(driver variability, weariness)*
  - Seamless integration *(with FMS/VMS)*
- **Maintenance reduction** *(per tonne hauled)*
  - Operator behavioural issues eliminated *(reduced component damage)*
    - *Increased Braking system maintenance (pad/disc life sometimes halved)*
  - Integrated onboard monitoring *(automated alerts)*
- **Safety**
  - No serious accidents to date *>370 trucks / 3B mt / 100M km)*



An EM tyre is a bit like a **Porsche 911** – a very highly developed…bad idea!

1. **Tyres are the primary limiting factor** for:
   - **Developing larger** haul trucks/other mining veh.
   - **Achieving potential productivity** offered by latest model large/ultra-class.

- **Biggest avail tyre** (>4m/1.5m) – max size for sea container & road freight restrictions.
  - **Building a larger tyre** pose severe **logistical challenges** *(but only ½ the story).*
- **Other componentry (incl engines)** can be scaled-up far more readily than tyres.
  - **Tyre designers** met their limits: size/capacity within price/life constraints.
    - **Want a HT larger** than 360/370t? > **Fit more tyres** (Belaz 450t 7571).

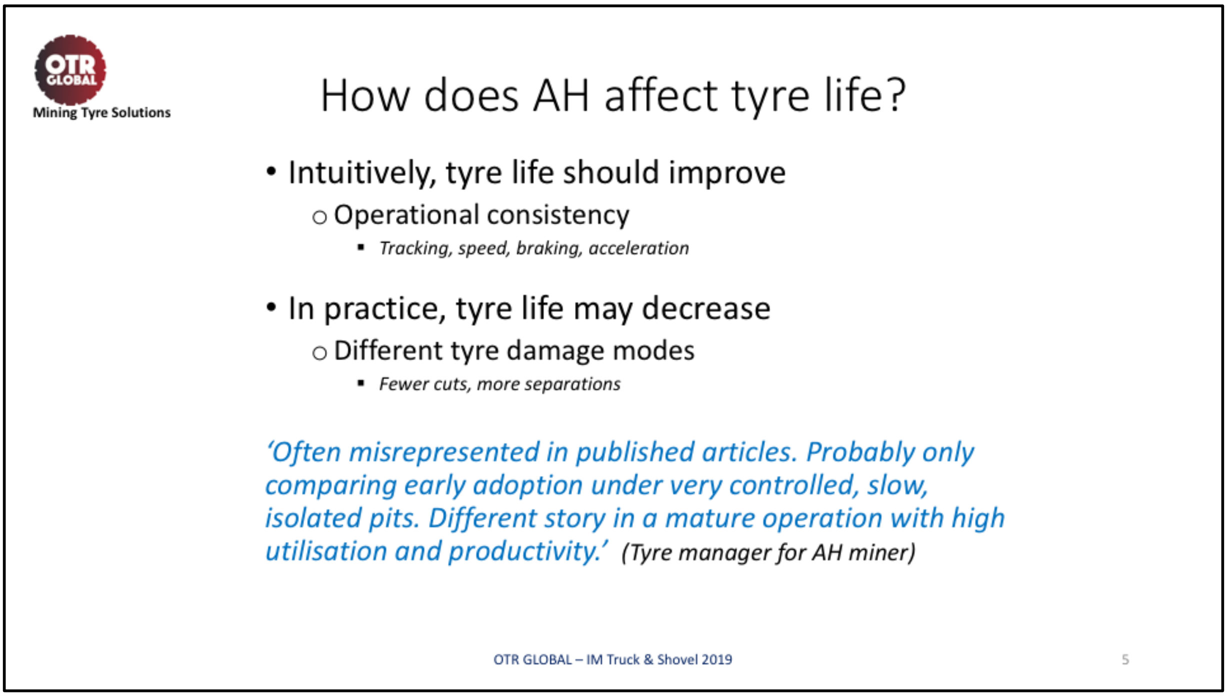
- **Latest model trucks** are rated at **over 60kph** on the flat at **full payload**.
  - Can maintain that speed at a max allowable **20% overload**.
  - **Tyre industry standard** (**50kph** @ full load) – **not kept pace** with HT devel.
  - **Net effect:** tyre speed/load capability **10-15% less** than latest model trucks.

2. **Truck size influences** the range of fit-for-purpose tyres.

- **12 f-f-p brands** can be fitted to a **95t.**
  - But **fewer** to each successively larger truck size,
  - **Only two** brands to **ultra-class** trucks *(kept up with HT development).*

3. **AHTs** are currently predominantly of **225t-up** capacity.

- **AHT users** presently strictly **limited** by brands of tyre **to tap the full potential** of AH**.**



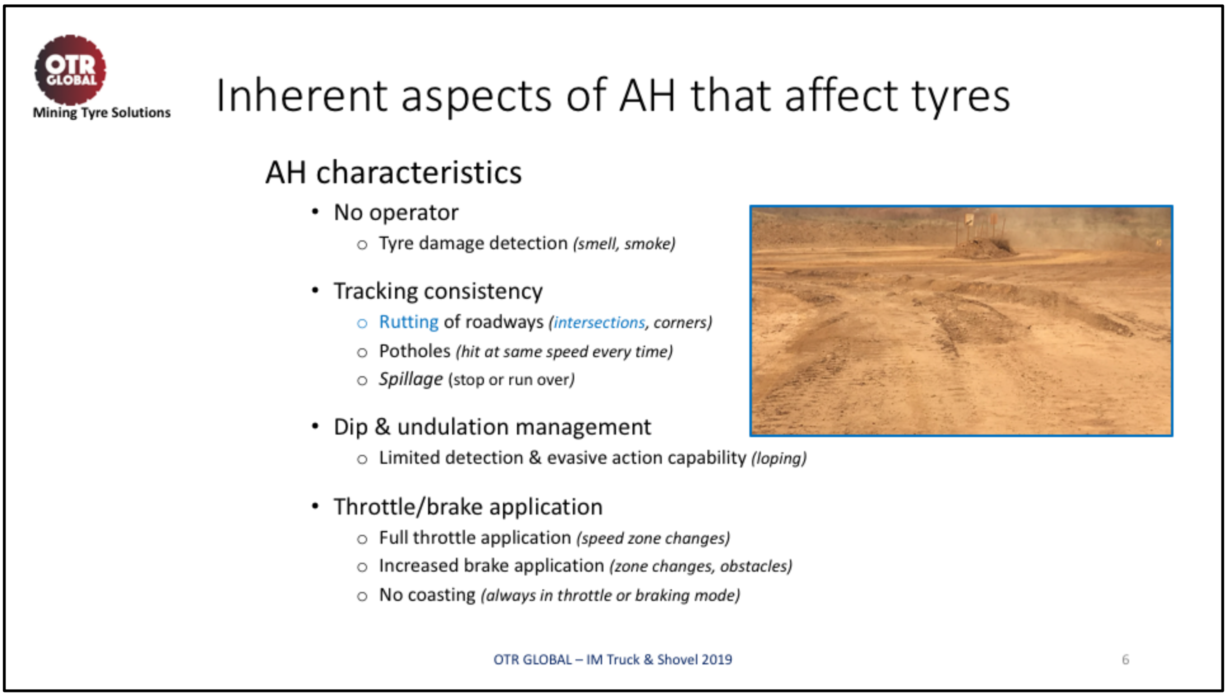
Articles on AHTs typically mention **increased tyre life**

- improvement ranging anywhere from **7 to 50%**.
    - The main stated reason is usually **consistency of operation**, together with **better haul roads** – a prerequisite for AH.

In some applications there may be an improvement in tyre life – although 50%...

- However, **in my experience**, tyre life can also drop significantly.
    - **usually accompanied** by a **change** in **dominant tyre failure** mode
        - *less rock cut* and penetration damage;
        - *more mechanical separation* damage to the tread.

➢ *The **tyre manager** for a major **AHT fleet operator** summed up his thoughts about claims of improved tyre life* (the **quote** at the bottom of the slide).

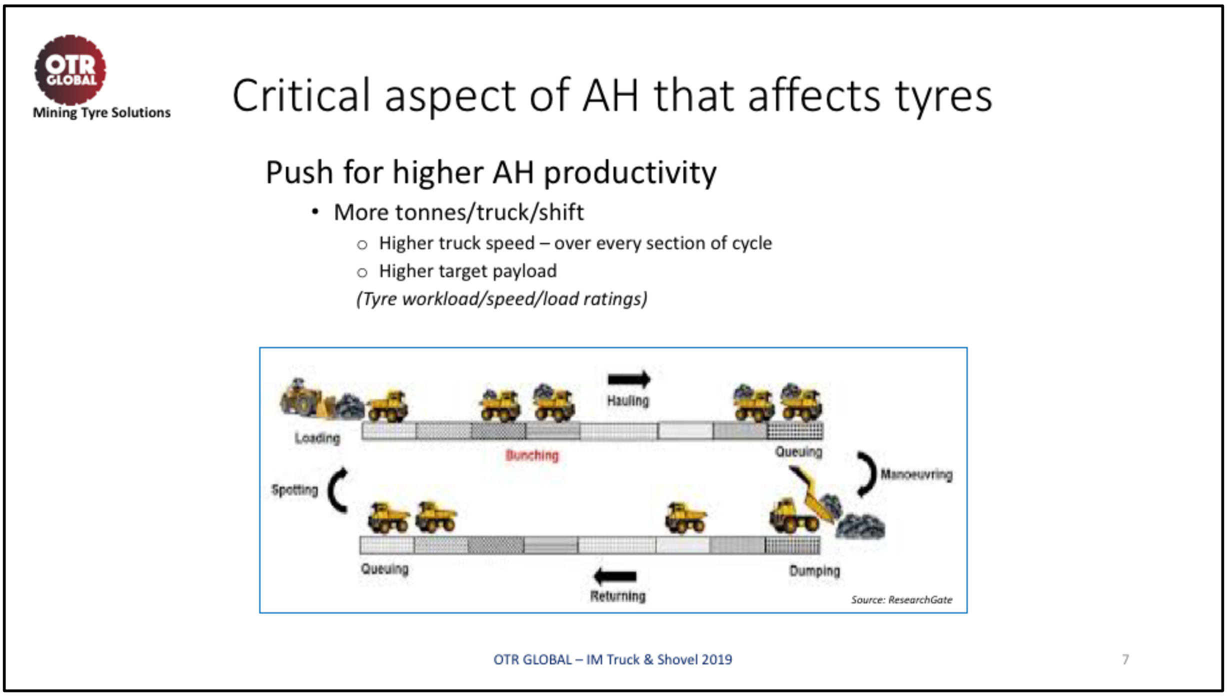


My experience limited to the two OEM systems in commercial op – so happy to be corrected!

AH affects tyres in a number of ways:

1. **No driver** – while many **benefits** (cost, consistency, etc); one major **downside**:
    - **Detecting tyre damage – especially tyre tread separation.**
        - Most AHTs are fitted with TPMS
            - *good for real-time tracking* of tyre **inflation pressure** & temp,
            - *ineffective for identifying* **tread sepo** before leads to **signif problem**.
2. **Other inherent** issues are:
    - Identical **tracking**
        - **Rutting** damage – particularly at *intersections*
            - Oil sands/summer *Komatsu: Multi-trajectory routes; Cat: Travel path indexing)*
        - **Manned truck** will avoid *pothole*; AHT hit it every time at same speed
        - **Spillage:** AHT may run over it, but usually stop > serious op. issues
    - **Not good** at identifying **road dips & undulations**, or reacting to them
        - **Loping** – chassis, suspension & tyres
    - ***Some*** systems: Full **throttle** application – *no coasting* (throttle or brake)

➢ *All of these AH characteristics increase the risk of tread sepo – espec. front tyres*

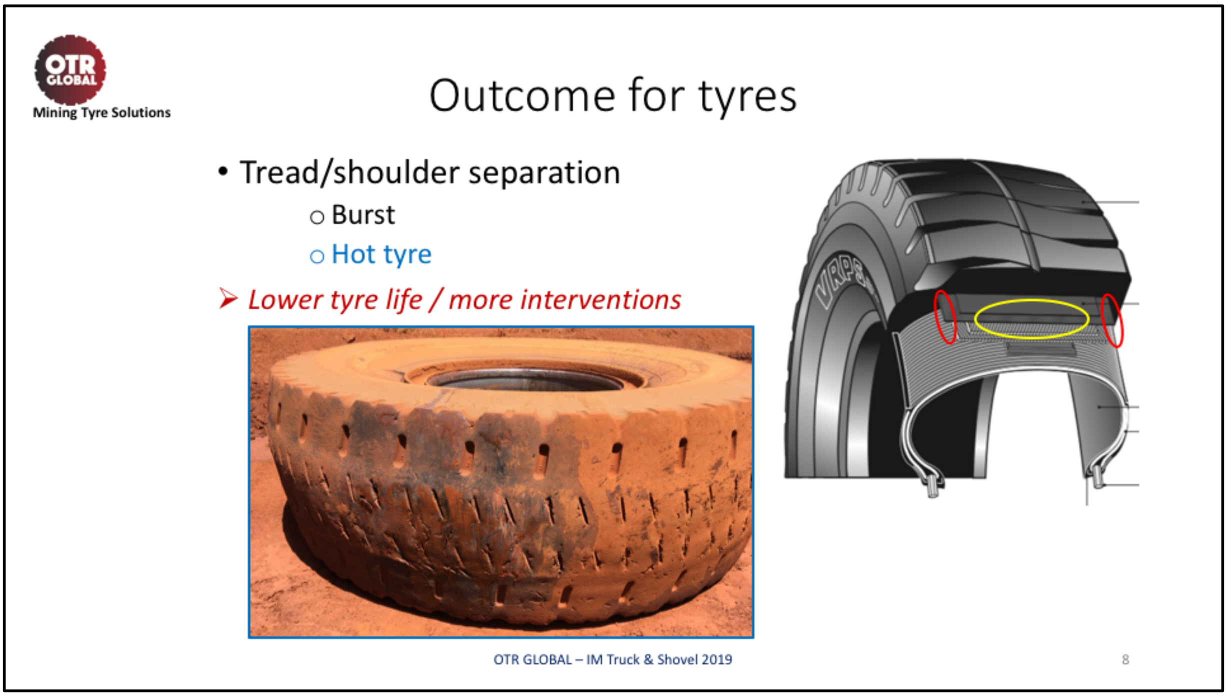


But the **real potential problem** for **tyres** – and ultimately **haulage TCO minimization**:

- Where the *quest* for **productivity** (main driver/benefit of AH) leads to:
  - **Targeting** of **truck** *speed* & *payload* **beyond** **tyre** *capability*.

➢ **Eventually** things will come **unstuck** unless the *various elements* are kept in **sync**:

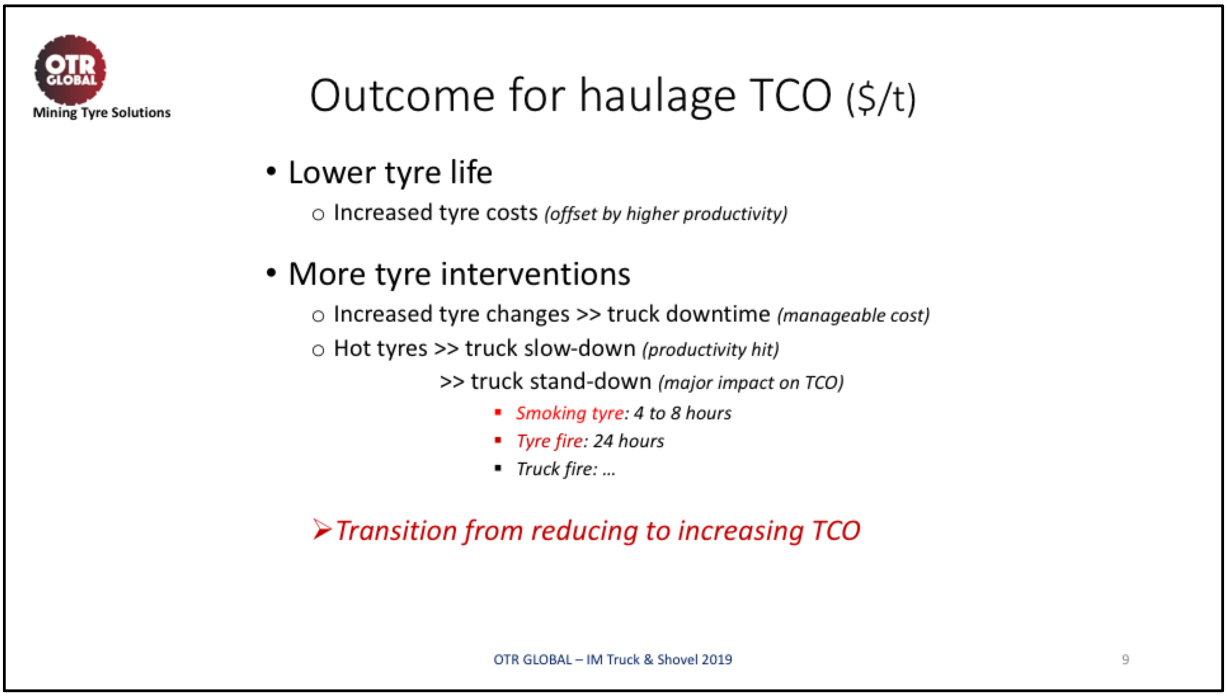
- Tyres, roads, speed & payload.



If that synchronization is not maintained, then the incidence of tyre tread separation will increase.

- **Construction** of radial tyre: discuss *casing*, *tread* & *tread belts*-6 of *(photo1)*
- **Tread separation** *is* where:
  - Steel tread **belts separate** from *tread*, *casing*, or *each other*.
  - Typically starts at belt-edge.
- *Tread separation* can **result** from**:**
  - Tyre running too hot – reducing component adhesion,
  - Mechanical stress that pulls the components apart.
- *Separation* **weakens** the tyre making it **susceptible** to:
  - **Impact** damage
  - Also **heats up** separated area through friction – contact patch.
- If tread separation **undetected** (no driver – *shift-start*; *bump/smell/smoke*
  - **End up** with **hot** (or smoking) **tyre** *(photo2).*

➢ ***Minimum adverse result:*** *premature tyre failure & increased level of tyre-related truck downtime.*



Any **push for higher** *truck* **speed** & **payload** will lead to:

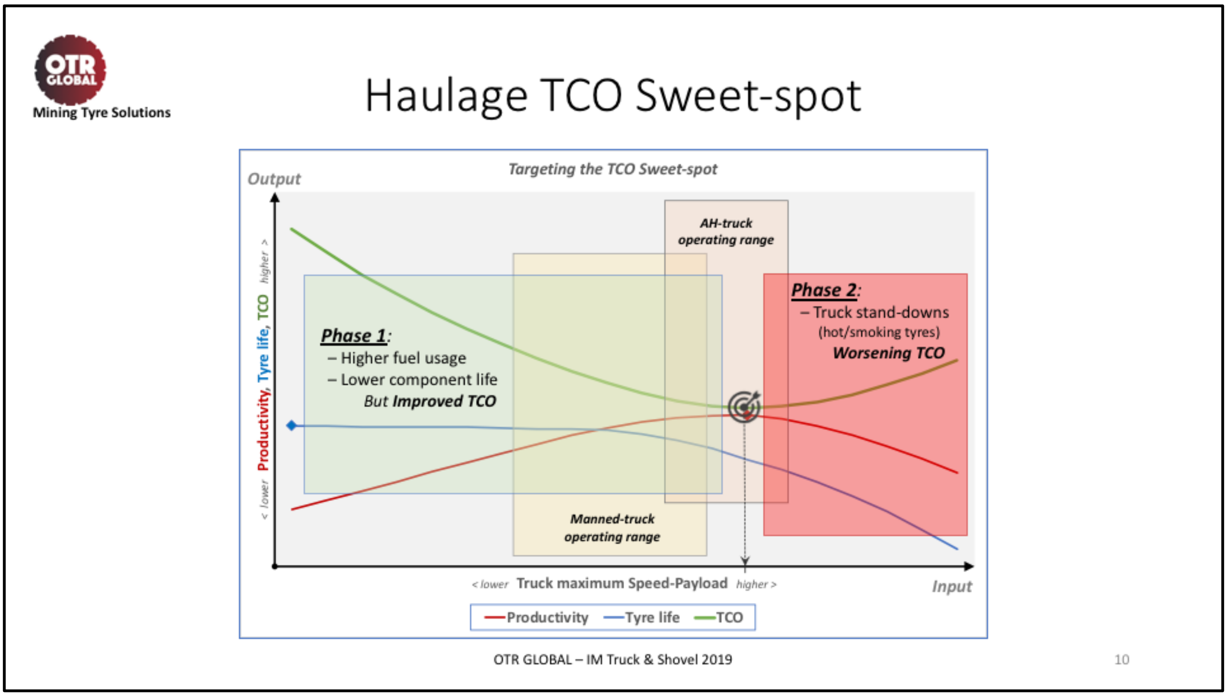
- **Lower** *tyre & component* **life** & **Increased** *maintenance* **interventions**
- If kept under **control**, extra costs more than **offset** by higher productivity.

- **TPMS** is **good** at **identifying:**
  - Hot tyres due to high average **workload** (TKPH)
    - *AHTs* typically *programmed* to **slow** down if inflat temp > 85C
    - **Affects** *production* but **manageable** if properly *controlled*.

- But **TPMS** will **not detect:**
  - Hot tyres due to mechanical tread separation
    - Can quickly develop into a smoking tyre
      - Truck stand-down: 4 - 8hr.
    - Unidentified smoking tyre will eventually catch fire
      - 24hr stand-down and isolation of the truck (300-500m)
      - Typically truck damage, sometimes destruction.

➢ **So, as truck speed & payload increase:**

- *Transition* from ***reducing*** to ***increasing*** *TCO*.



This is **demonstrated in this diagram**.

- **Bottom** *(inputs)* **axis** shows *increasing truck* **speed** & **payload**.
- **Vertical** *(outputs)* **axis** shows *tyre/comp* **life**, *truck* **productivity** & *haulage* **TCO**.

In **Phase 1:** **increasing** *truck* **productivity** (higher *speed* & *load*)

➢ *More* than **compensates** for **reducing** *tyre/comp* **life**.

Then we hit the TCO sweet spot.

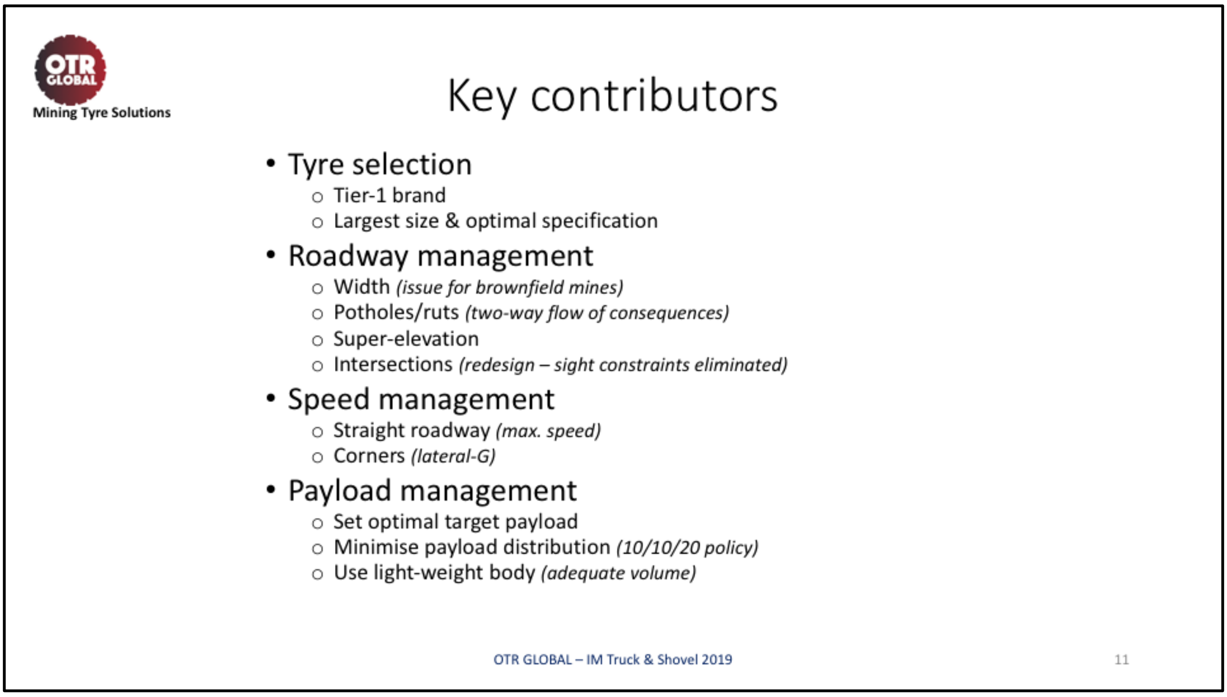
Phase 2: As truck **speed** & **load** ***increase beyond*** this point; we get increasingly:

➢ **Lower life** *(tyres, componentry)*

➢ ***And*** *production* **downtime** *(due to tyre interventions)*

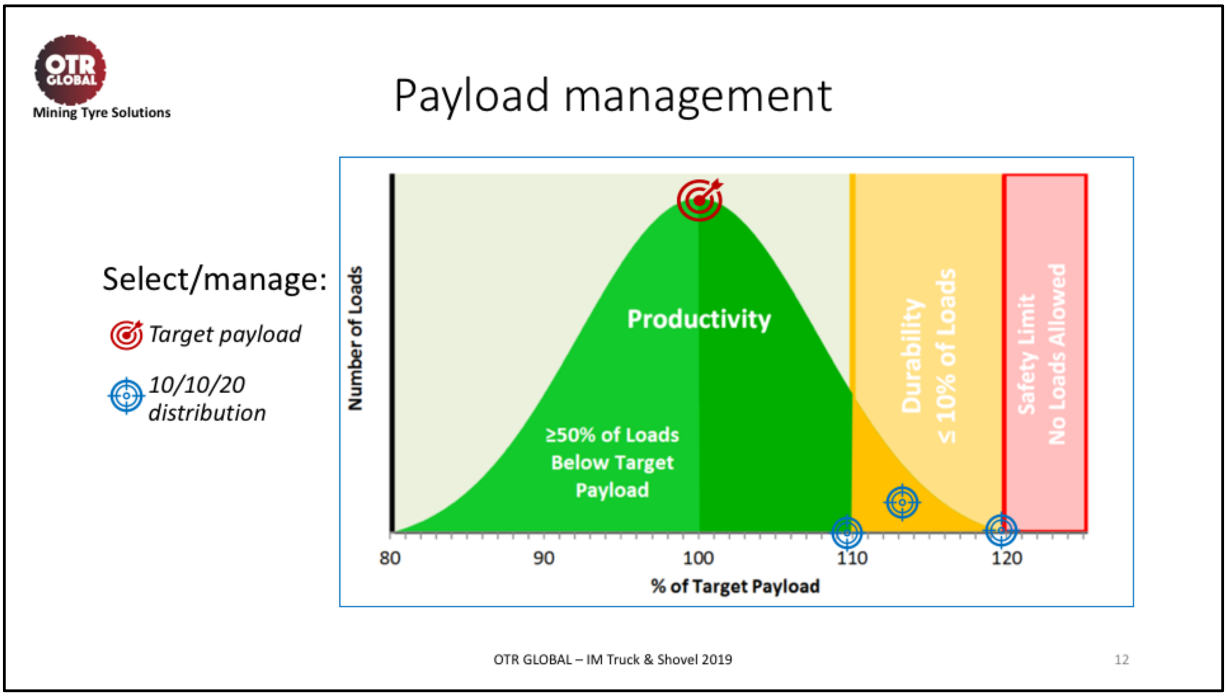
➢ **Dropping** *productivity* & **Deteriorating** *haulage TCO*.

- ***Manned*** trucks usually operate in *Phase 1 zone*.
- ***AHTs*** can *straddle* both zones.



These are **key contributors -** essent to getting **full productivity potential** from AHT fleet.

- Only **tier-1** tyres**,** **largest** *optional size* & *appropriate* **compounding**.
- **Design & construct roads** correctly
  - **Competent** *material*
  - **Free** of *dips*
  - **Largest** *radius* possible *(curves/ inters), properly* **Super-elevated** *(survey control)*.
    - **Less damage** *to trucks, tyres, roads*
    - **Reduced** *road maintenance requirement*
      - ***Less interaction*** *manned cleanup equip & AHTs.*
- Careful **management of truck speed**
  - **Absol max** flat-haul speed *(may involve trial & error*): *40kph (25mph) > 45/50/open*
  - **Speed** for each **curve & corner** based on radius/super-elevation *(<0.05 /0.1Gy*)
- Carefully **manage truck payload** *(& load distribution by tyre)*.
  - If *productivity critical*, use a **light-weight bo**dy (ensure *volume* capacity).
    - Rectify *tare weight distrib anomalies* / *Fine-tune suspension* setup / Trim headboard
  - Carefully **select target payload** (*trial & error*)
  - **Control** *payload* **variance**
    - Requires best loading equipment *operators*, *training* & tech *tools*.



Payload management involves **selecting the target** payload & **limiting payload** variance.

The **10:10:20 policy**, developed by Caterpillar, has become the industry standard:

- **No more than 10% of loads** more than 10% over target payload & **never exceed** target payload by more than 20%.

➢ *The **following three slides** show the result of a weigh-scale study conducted on three separate haul truck fleets operating on a single mine.*

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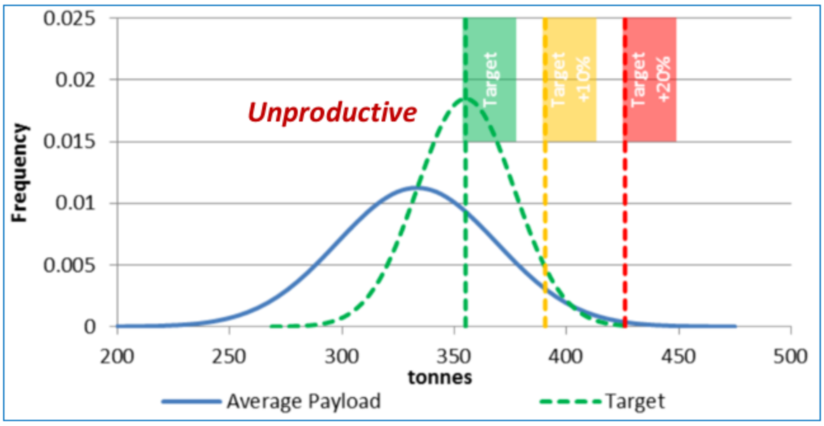
Payload: *under-target/excessive spread*



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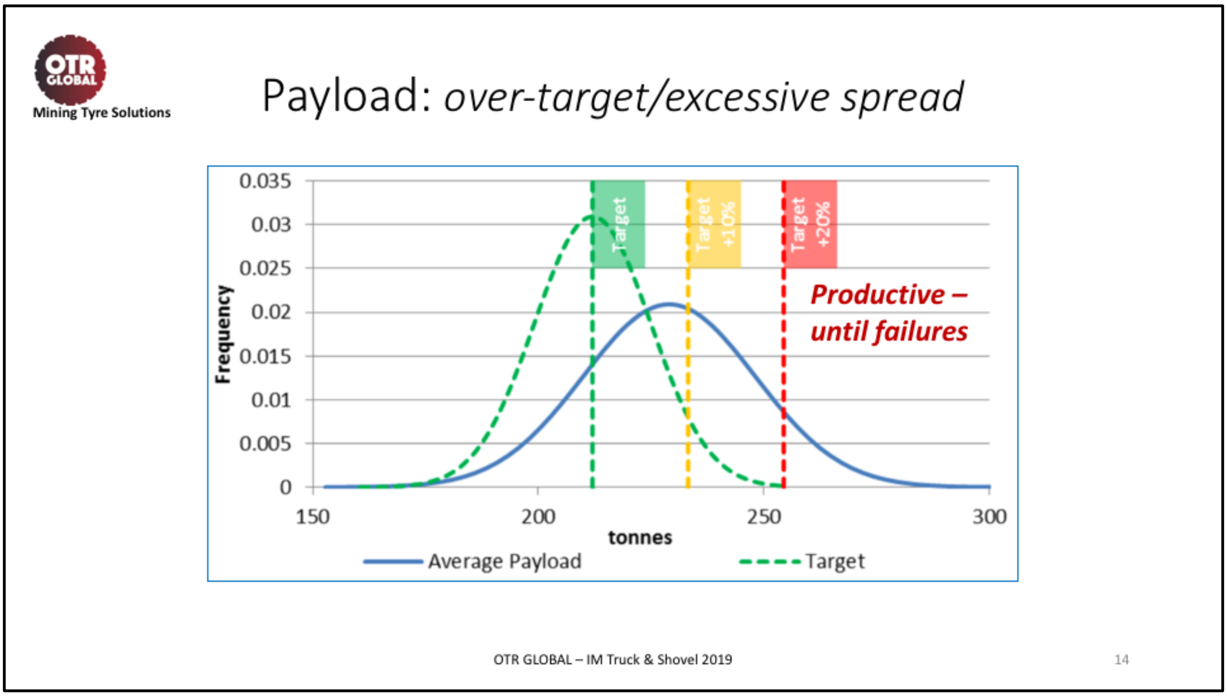
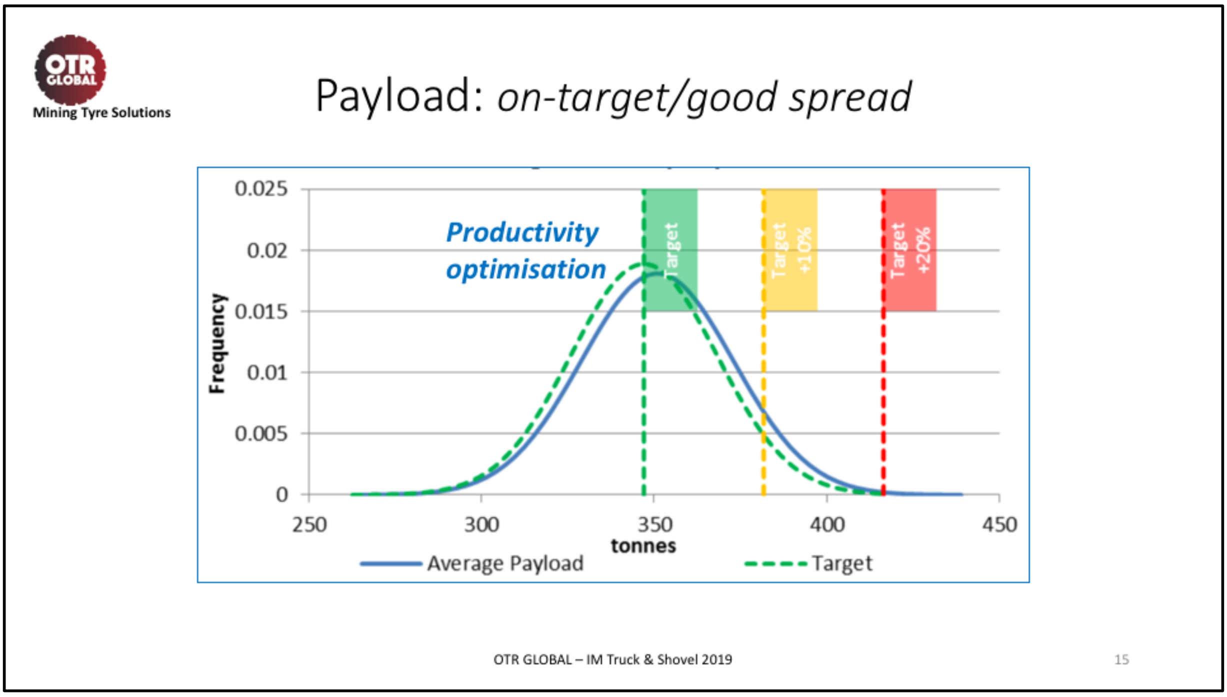
360t truck fleet – *seriously underproductive* with *very poor control*



220t truck fleet – *seriously overloaded*.

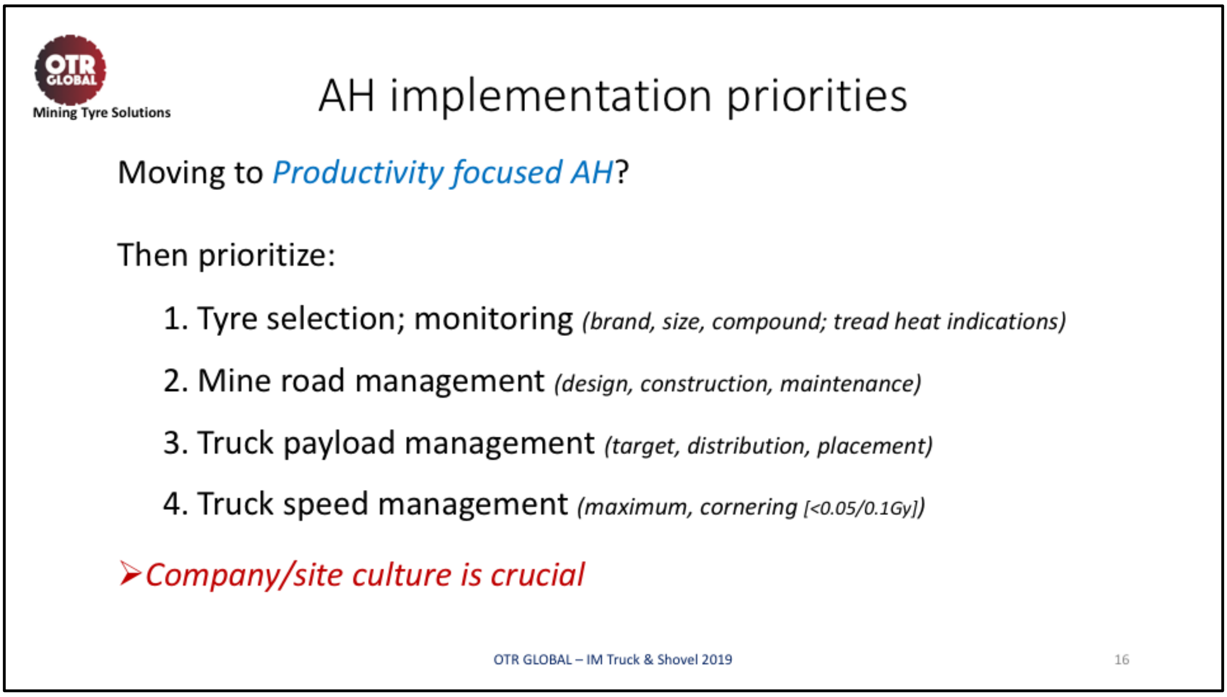
Productive until truck ***chassis failures*** loom.

- This slide is generally representative of historical payload practice in the Australian mining industry.



360t truck fleet – pretty much *right on the money*

- This case study suggests that **mine culture was** *not* the main issue for anomalous payload results (1 fleet good, others poor)
    - Perhaps material **SG** issues for one or other truck fleet
    - Perhaps **body size** & **design** – critically *important*!



If a mine plans to move to ***productivity*** focused **AH**, then:

Tyre quality is ***critical***

- **Use only tier**-1 tyres; using *tier-2 tyres negates* AH benefits (productivity, maintenance & safety).
    - *Don't rely on AH* to make a tier-2 tyre perform better.

Really need **real-time monitoring** of the tyre tread

- **Not currently provided** by *OEMs*; no *3rd party* offering
    - A system *needs* to be **developed!**

Mining companies are not renown for building good haul roads.

- Common failings:
    - Unsuitable *material*, inadequate *compaction*, poor intersection *layout*, excessively tight *turn-radii,* lack of *super-elevation*.

Truck payload & speed management is critical

- *This is what can bring things apart very quickly* – especially if there are any *issues with tyre or roadway quality*.

Company & site culture play a crucial role

- AHS operation must be structured; as James Petty said in 2017 paper:
    - *'there is no room for a "pit boss" in an autonomous mine'.*

➢ *'The performance of an autonomous mining system will be influenced more by the operation of the site than the technical functionality of the system.'*

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Rules of Automation

- *"The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency.*
- *The second is that automation applied to an inefficient operation will magnify the inefficiency."*

Bill Gates

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I'll leave you with Bill Gates' *two rules of automation*.

- **The application of AHS** at mine sites has *never failed* to work **but** there are cases where it has *failed to meet expectations*.

End of presentation – Thank you

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End of presentation.

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Tyre size nomenclature *(examples)*

90mt (Cat 777, Kom HD785):	*27.00R49*
135mt (Cat 785, Kom HD1500):	*33.00R51*
180mt (Cat 789, Kom 730E):	*37.00R57* *40.00R57*
218-225mt (Cat 793, Kom 830E):	*40.00R57* *46/90R57* *50/80R57*
290mt (Cat 794AC, Kom 930E):	*53/80R63*
370mt (Cat 798AC, Kom 980E):	*59/80R63*