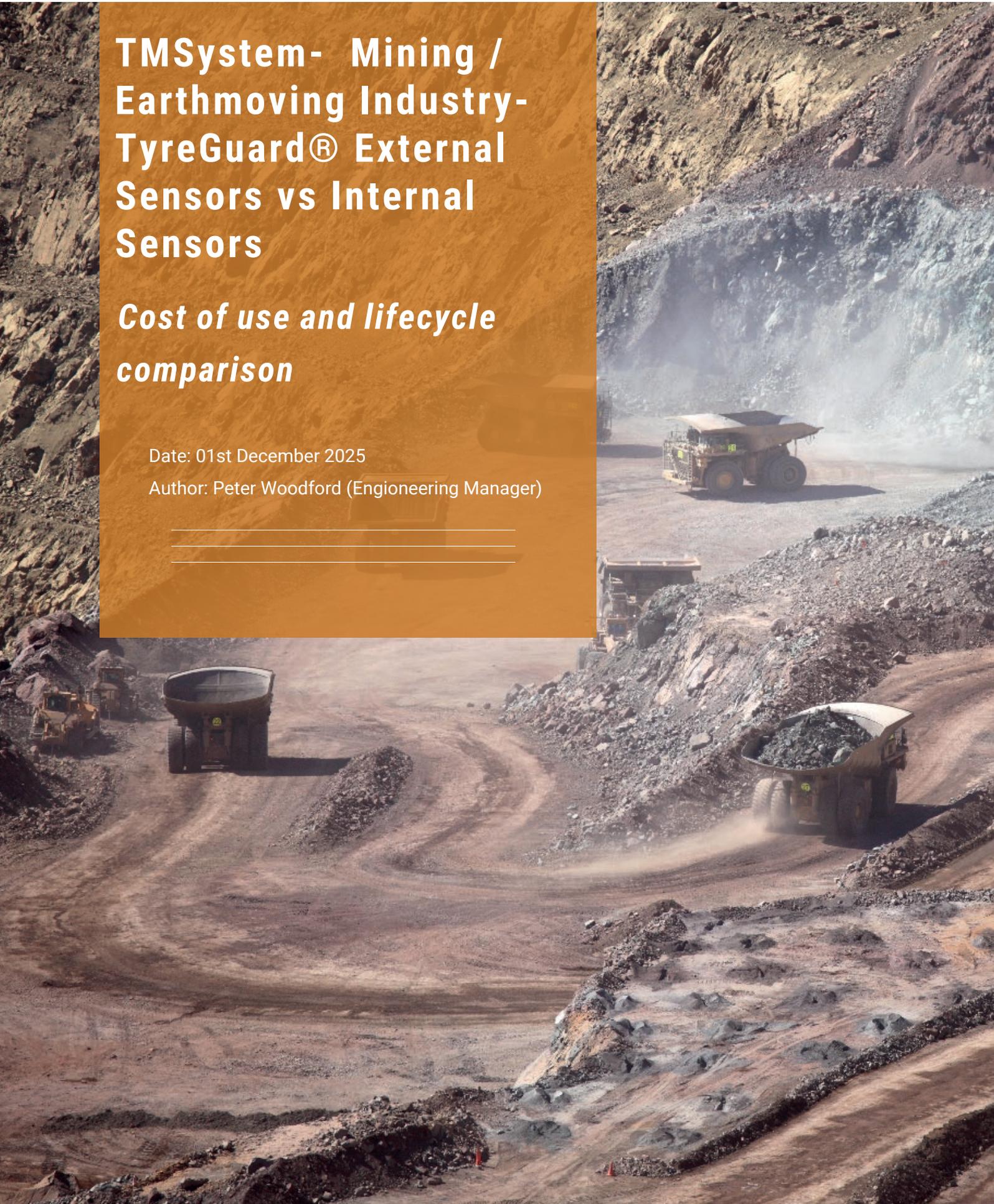


TMSystem- Mining / Earthmoving Industry- TyreGuard® External Sensors vs Internal Sensors

Cost of use and lifecycle comparison

Date: 01st December 2025

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■ TBulletin: OTR TMSystem with Internal vs External Sensors Comparison

1. BACKGROUND / SUMMARY.

This report provides a detailed technical, operational, safety, and whole- of- life cost comparison between:

- LSM TyreGuard® CE360- an External valve- mounted OTR TMSystem Sensors.
- Typical Internal Sensors that are primarily attached to the inner wall of OTR tyres (some Rim mounted Sensors are also available) along with similar Internal Sensor OTR systems.
- This discussion paper is primarily focused on vulcanised Sensors that re attached to the inner wall of the OTR tyre.
- This analysis / discussion paper is specifically framed for mining / earthmoving operations, including:
 - Ultra-class haul trucks (e.g. CAT 797, 793, Komatsu 930E, Liebherr T284).
 - Loaders, graders, drills, water trucks, and support equipment, and
 - Both open-cut and underground fleets.

Key conclusions derived from the analysis:

- TyreGuard® External Sensors provide equivalent pressure accuracy and practical temperature monitoring compared to Internal Sensors, but with dramatically lower safety exposure, downtime and lifetime cost because the tyre does NOT require removal for replacement of a Sensor.
- Internal Sensor TMSystems require full tyre strip- down for each Sensor failure or battery end- of- life replacement event. This introduces significant safety risks, increased downtime, loss production, operational risk, long delays where equipment is still in operation with failed Sensors and high economic cost per incident.

2. SAFETY & REGULATORY ALIGNMENT.

TMSystems are becoming increasingly mandated by industry, regulators, and safety advocates in all industries due to their inherent proven benefits for safety. As an example, today every manufacturer in the world must include TMSystems in the manufacture of their passenger vehicles.

In regard to the Mining and Earthmoving Industry and large earthmoving machines, this section of the discussion paper is relative to how each TMSystem should or must align with Australian mining tyre and rim safety guidance, recommendations, and regulations.

2.1 Safety Regulations / Guidelines / Mandates.

LSM TyreSense® External Sensors comply with the following:

- [2014- Coroner Report- Foxleigh fatality](#): recommendations to be implemented within 2 years from Oct 2014.
- [2015- CICA \(Crane Industry Council\)](#): recommended for Articulated Cranes.
- [2015- WA DMP \(Department of Mines and Petroleum\)](#): Tyre Management Guidelines not just for OTR Machines- but for all rubber tyre vehicles.
- [2016- DNRME- Coroner Cut- off Date TMSystems](#): Compliance reminder for implementing TMSystems mitigation controls on heavy vehicles.
- [2016- Queensland Nov Tyre Wheel + Rim Management Standard 13](#): Department of Natural Resources and Mines (DNRME).
- [2017 TfNSW Mandates TMSystems for Buses \(BC17/18562\)](#): to mitigate Wheel Well Fires on Buses.
- [2021- ARTSA-Institute- Heavy Vehicle Fires](#): Cause and Prevention Study.
- [2020- TfNSW recommended Safety Features + Technologies for Heavy Vehicles.](#)

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2.2 Testing and Certification.

TMSystems and Sensors are also tested, certified and compliant to:

- CE + FCC and [ACMA](#) RCM Tick.
- [SAE J2848](#) Tyre Pressure Systems- Management (CTIS) Type for Medium and Heavy Duty Highway Vehicles.
- [SAE J1455](#) Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications.
- [EN ECE R-141](#) European regulation / mandate for TMSystems (and CTI Systems).
- Tested and certified for Dangerous Goods Transport- 2016 [Kleenheat reference](#) tested by Inlec Engineering (WA).
- Compliance to DEMIRS WA [ANE DG Transport Code of Practice](#).

2.3 Guidance Emphasis.

These guidelines emphasis:

- Continuous monitoring of tyre pressures and temperatures in service.
- Minimisation of human exposure to tyre- handling hazards.
- Early detection of abnormal temperature / pressure conditions.
- Controls to reduce the risk of tyre fires, explosive failures, and catastrophic incidents.

a) **Internal Sensors:**

- Requires hazardous tyre- handling for every Sensor / battery replacement.
- Can create periods of unmonitored running while waiting for tyre- change windows.
- Increases exposure to dangerous tyre operations.

b) **TyreGuard® External Sensors:**

- Eliminates the need to strip a tyre purely for TMSystem maintenance.
- Greatly reduces exposure to high- risk tyre- handling events.
- Supports consistent, real-time pressure and temperature monitoring.
- Aligns strongly with the intent of Mining / Earthmoving Tyre and Rim management standards to reduce tyre- handling risks while improving monitoring.

3. SENSOR ARCHITECTURE- INTERNAL VS EXTERNAL.

The major fundamental architectural difference between Internal and External Sensor designs:

3.1 Internal Sensors:

- Sensors are mounted inside the tyre cavity on the rim.
- Any Sensor replacement (failure or battery depletion) requires full tyre removal from the rim.
- Tyre must be deflated, bead broken, lock rings removed, tyre removed, Sensor accessed / replaced, then tyre re- fitted and re- inflated.
- This process is labour- intensive, dangerous, and time-consuming.
- There is a significant risk of Sensor damage during tyre mounting and removal.
- If a Sensor fails while a tyre is in service, the vehicle may operate unmonitored for an extended period until a tyre change is scheduled.

3.2 External Sensor (TyreGuard®)

- Sensors are mounted externally on the large- bore valve stem of the rim / tyre.
- The tyre does NOT need to be removed from the rim to replace or reprogram a Sensor.
- Sensor replacement can be done safely in the field in minutes.
- This eliminates the need for a hazardous tyre strip solely for TMS maintenance.

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- There is no risk of Sensor damage during tyre fitment or removal because the Sensor is not inside the tyre cavity.
- The duration of any unmonitored running (after a failure) is minimised to a few minutes while the external Sensor is replaced.

The design is rim- agnostic and tyre- agnostic, allowing mines to use any wheel / rim supplier.

4. SENSOR ACCURACY – PRESSURE AND TEMPERATURE.

We examined the published and implied accuracy of both systems / Sensors. The consensus is that accuracy is effectively equivalent and is not the differentiator between systems.

4.1 Pressure Accuracy.

- External Sensors (TyreGuard®) technical specifications list pressure accuracy of 6.89 kPa, which is approximately ± 1 psi over its operating range.
- Internal Sensors mining literature describes its wheel Sensors as accurate to within ± 2 psi of actual pressure levels.
- **Conclusion (Pressure):** Both system Sensor types are effectively equal in pressure accuracy ($\sim \pm 2$ psi).
- From a practical heavy mining tyre perspective, this is more than adequate and there is no meaningful performance difference.

4.2 Temperature Accuracy.

- External Sensors (TyreGuard®) are within $\pm 1^\circ\text{C}$ temperature accuracy.
- We were unable to attain Internal Sensors published $\pm^\circ\text{C}$ temperature accuracy figures in publicly accessible documentation.
- Internal Sensors emphasises that an internal Sensor reflects internal chamber conditions .
- External Sensors (TyreGuard®) provides external temperature sensing with high- temperature alarms (e.g. around 80°C) and is aligned with Australian mining tyre safety guidance.

In practice, both systems provide sufficiently accurate temperature data to:

- Detect abnormal heating or tyre / rim.
- Trigger alarms, and support temperature trend analysis.
- **Conclusion (Temperature):** Both systems are accurate enough for mining alarm and trend purposes. The decisive differences between systems are in serviceability, safety exposure, and cost, not pressure / temperature accuracy.

5. SENSORS FAILURE BEHAVIOUR AND SERVICEABILITY.

5.1 Internal Sensors.

Examination of published information about Internal Sensors reliability and how failures are handled operationally.

Key observations:

- Documentation describes Internal Sensors as reliable and best- of- class and installation manuals state that patch failures are low when installed correctly.
- The system includes explicit alerts for Sensor Fail and Low Battery, which confirms that Sensor failures do occur and must be managed.
- Internal Sensors are subject to:
 - Battery depletion.
 - Adhesive / patch fatigue.
 - Liquid ingress.
 - Damage during tyre mounting and removal.
 - Heat and vibration stresses.

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Consequences of failure for Internal Sensors.

- Every Sensor failure, battery end- of- life event, or Sensor damage case requires a full tyre strip.
- This means deflation, bead breaking, lock-ring handling, tyre removal, Sensor replacement, re-seating, and re-inflation.
- As noted, this exposes technicians to significant danger and causes non- trivial downtime.
- The vehicle may also run unmonitored until the next suitable tyre maintenance window, increasing risk of tyre- related incidents.

5.2 External Sensors.

Examination of published information about External Sensors reliability and how failures are handled operationally.

Key observations:

- External Sensors (valve- stem mounted) are generally considered easy to install / service with emphasises quick replacement without tyre removal.
- Documentation from multiple brands confirms the presence of Sensor Fail, Low Battery, and No Signal alerts reinforcing that External Sensor failures also occur and must be managed.
- Unlike Internal Sensors, External Sensors are exposed directly to the environment and therefore subject to different failure modes.

External Sensors are subject to:

- Environmental exposure but are designed (potted silicon) to ensure dust, water, chemical spray, mud, corrosive mine environments.
- Although mechanical impacts are possible, External Sensors (TyreGuard®) are designed for severe impact and can be additionally protected with simple, low-cost shielding.

Consequences of failure for External Sensors

- No tyre removal required for replacement of the majority of failure types.
- A failed external sensor can generally be swapped out in minutes.
- Repair or replacement is field-serviceable and can usually be done- eg during fuelling, at the pre-start area, shift change, or meal breaks.
- Reduced technician risk exposure because bead breaking, lock-ring handling and full tyre disassembly are not required.
- Vehicle operation can continue with minimal interruption, as downtime is significantly lower compared to internal sensor replacement.

6. TIME AND COST IMPACT- INTERNAL SENSOR FAILURE SCENARIO.

We will now consider a cost analysis using a specific example is a CAT 797 ultra-class haul truck, which uses 59 / 80R63 tyres weighing approximately 5.5 tonnes.

Cost Components for a single **Internal Sensor** Replacement Event on a CAT 797:

6.1 Time to Change a CAT 797 Tyre:

- Approximate tyre-change duration: 3.0 hours.
- Requires two dedicated, highly trained OTR tyre technicians.
- Requires specialised lifting, bead-breaking, and inflation equipment.
- LSM technical material notes that internal TMS replacement can take anywhere from several hours to a full day depending on workshop queues and vehicle type.

6.2 Labour / Workshop / Equipment:

- 2 technicians x 3.0 hours plus overheads and equipment usage.
- Estimated cost: approximately \$3,000- \$5, 000 per event.

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6.3 Production Hours:

- Large haul trucks in mining operations often have an economic production value of roughly **\$160 000 (3 x loads / hour)- \$350, 000 (5 x loads / hour)** for say Iron Ore (A\$105 / tonne).
- For a 3.0 hour tyre change window, lost production is approximately **\$480k-\$ 1.05 million**.
- In terms of a loss 12 hours day (typical tyre bay queueing, travel, setup, strip, re-fit, pressure stabilisation, and return-to-service time seen in real mines) could escalate to **\$1.92- \$4.2 million**.

6.4 Internal Sensors TMSystem Hardware Cost:

- Trade data information shows a 6 x position Internal Sensors kit valued around **\$13,000**.
- Individual mining- grade Internal Sensors can reasonably fall in the **\$800-\$1,500** per Internal Sensor.

7. TIME AND COST IMPACT- TYREGUARD®- EXTERNAL SENSOR EQUIVALENT FAILURE SCENARIO.

In contrast, the TyreGuard® External Sensor failure would be managed operationally.

7.1 Production Loss per Event.

Estimated Cost per **External Sensor** Replacement Event:

- The truck is parked safely (or serviced during other routine checks).
- A technician walks to the wheel, unscrewing the external Sensor from the valve.
- A new External Sensor is installed.
- The Sensor ID is reprogrammed / registered into the Monitor.
- The process typically takes only a few minutes.
- Labour: around 10- 15 minutes of a technician's time.
- Vehicle downtime / production loss: negligible, often can be aligned with pre-start or other scheduled minor maintenance / refuelling, etc time.

7.2 External Sensors- TMSystem Hardware Cost.

- A typical TyreGuard® TMSystem with 6 x position Internal Sensors kit valued around **\$4, 000-\$5,000**.
- Individual External Sensors (Conditioner Fluid resistant) in the \$400- \$500 per External Sensor.

TMSystem with External Sensors have a commercial advantage of the Internal Sensor architecture.

8. THE FINANCIAL CASE FOR EXTERNAL SENSOR TMSYSTEMS.

It is accepted that the **greatest cost impact** comparison between Internal and External Sensors is the downtime / loss of production.

Subsequently, we will now provide an analysis of such impacts based upon assumptions of a **1 x year and 5 x year costs** for:

- 1 x Caterpillar 797 Dump Truck.
- Fleet of 20 x Caterpillar 797's.
- All figures consider production loss only (no Sensor hardware or labour), so this is the *avoidable* cost of choosing Internal Sensors vs External Sensors.

8.1 Assumptions.

- **Truck type:** Caterpillar 797 (6 x monitored wheel positions).
- Operating profile:
 - 350 production days per year.
 - 20 hours / day- 7,000 hours / year.
 - Over 5 years- **42,000 hours**.

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8.2 Sensor Service Life (Internal & External).

- Assume nominal 5 x year service life for both types in this duty.
- With 6 x Sensors per truck, that's 6 x Sensor Replacement Events (SRE) over 5 years.
- Approximately 1.2 Sensor replacement events per truck per year (on average).

8.3 Production value (loss) per hour.

- Low case: \$160,000 / hr.
- High case: \$350,000 / hr.
- Mid **case (for "typical")**: \$250,000 / hr (midpoint).

8.4 Internal- Sensor downtime per Event.

- Low: 3 hours (very optimistic- quick bay access, no queuing).
- Typical: 6 hours (travel, queue, strip, re-fit, test, return).
- High: 12 hours (night shift, queue, delays, shift change etc.).

8.5 External- Sensor downtime (TyreGuard®).

- SRE in minutes, done inline with other checks- assume zero material production loss.
- So the only production- loss cost we model is for Internal Sensors.
- TyreGuard® External Sensors are effectively zero production- loss, by design.

9. ECONOMIC IMPACT ANALYSIS- CAT 797 HAUL TRUCK - PRODUCTION LOSS MODELLING.

Internal TMSystem External (TyreGuard®) vs Internal Sensors.

Purpose of this Analysis

- This page quantifies the production loss cost potentially caused by TMSystem with Internal Sensors that require tyre removal to SRE for failed sensor or expired battery (end- of- life).
- The analysis compares that loss against TyreGuard® External Sensors, which can be replaced in minutes without tyre strip, resulting in near-zero production loss.
- We will consider a SRE due to failure in the field (unscheduled downtime / in operation) of 1 x Sensor / Truck each year. However more frequent failure rates could occur

10. OPERATIONAL BASIS AND ASSUMPTIONS.

| Parameter | Value / Assumption |
|---|---|
| Truck Type | Caterpillar (CAT) 797 (6 monitored wheels) |
| Production Days | 350 days / year |
| Production Hours | 20 hrs / day (7,000 hrs / year) |
| Sensor Life Replacement (Internal / External) | 5- 6 years (6 x Sensors) |
| Sensor Failure Rate (estimate) | 1 x events / year (could be more) |
| External Sensor Impact | Zero downtime (minutes; completed during other checks) |
| Internal Sensor Downtime | 3 hrs (low) · 6 hrs (typical) · 12 hrs (high) |
| Production Value per Hour | \$160k (low) · \$250 (typical) · \$350k (high) |

- All costs below represent **avoidable losses** inherent only to Internal Sensor systems.

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11. PRODUCTION LOSS PER CAT 797.

11.1 Annual Impact- Single Truck.

This considers production loss for a **single SRE** on a **Single Truck** each **Single Year**.

| Scenario | Downtime / hr / Sensor | \$/hr | Annual Production Loss- Single SRE |
|--------------|------------------------|--------|------------------------------------|
| Low Case | 3 hrs | \$160 | 0.48 M |
| Typical Case | 6 hrs | \$250k | 1.5 M |
| High Case | 12 hrs | \$350k | 4.2 M |

- **TyreGuard® External Sensors: - \$0** production loss (no tyre removal required).

11.2 Production Loss per CAT 797- 5 x Year Life.

This considers production loss for replacement of **ALL Internal Sensors** (6 x off) on a **Single Truck** every 5 x years + **1 x single** unscheduled **SRE** in a **single year**- over 5 years.

| Scenario | A. Total replace all 6 x Sensors (every 5 x years) | B. Single Fail SRE / Annum / for 5 Years | A+B Total estimated Production Loss- 5 x Years / Single Truck |
|--------------|--|--|---|
| Low Case | 0.48 M x 6 = \$2.88 M | \$2.4 M | \$5.28 M |
| Typical Case | 1.50 M x 6 = \$9.0 M | \$7.5 M | \$16.5 M |
| High Case | 4.2 M x 6 = \$25.2 M | \$21 M | \$46.2 M |

- **External Sensors: No tyre removal, so near-zero downtime \$0** production loss over 5 years.

12. FLEET IMPACT- 20 X CAT 797 HAUL TRUCKS.

12.1 Impact (20 Trucks)- Annually.

Using the above calculated estimates, this considers production loss for Annually for a Fleet of 20 trucks.

| Scenario | Annual Production Loss per Truck | Fleet of 20 Trucks |
|----------|--------------------------------------|--------------------|
| Low | \$5.28 M / 5 years= \$1.056 M | \$21.12 M |
| Typical | \$16.5 M / 5 years = \$3.3 M | \$ 66.0 M |
| High | \$46.2 M / 5 Years = \$9.24 M | \$ 184.80 M |

12.2 Impact (20 Trucks)- 5 x Years.

Using the above calculated estimates, this considers production loss for 5 x Years for a Fleet of 20 trucks.

| Scenario | 5 x Year Production Loss / Truck | Fleet of 20 Trucks |
|----------|----------------------------------|--------------------|
| Low | \$1.056 M * 5= 5.28 M | \$105.6 M |
| Typical | \$3.30 M * 5= 16.5 M | \$270 M |
| High | \$9.20 M * 5= 46.0 M | \$648 M |

- **External Sensors: No tyre removal, so near-zero downtime \$0** production loss over 5 years.

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13. SUMMARY- COMPARATIVE ADVANTAGES – TYREGUARD® EXTERNAL VS INTERNAL SENSORS.

In summary, the following comparative points were repeatedly highlights the technical and commercial advantage and benefits of **External Sensors** vs **Internal Sensors** such as:

13.1 Internal Sensor Architecture.

- Forces tyre removal- major production downtime.
- Costs escalate rapidly due to high hourly production loss.
- Even “conservative” cases produce multi- million- dollar losses per truck.

13.2 External Sensor Architecture.

- Sensor replaced externally in minutes.
- No tyre strip, no downtime, no production loss.
- Fleet value preserved.
- Major safety advantage..
- Reduces risk of unmonitored running (pyrolysis & fire prevention).

13.3 Operational Advantages.

- Field- replaceable External Sensors, no tyre removal required.
- Rapid restoration of full TMSystem functionality after a Sensor failure.
- Rim- agnostic design allows flexibility in wheel / tyre selection.
- Simplified training and operation- no special skills required for SRE.

13.4 Safety Advantages.

- Avoids unnecessary bead breaking, lock-ring handling, and heavy lifting.
- Reduces technician exposure to one of the most dangerous maintenance tasks on a mine.
- Minimises chance of TMS Sensor damage during tyre service work.

13.5 Commercial Advantages.

- External Sensors and TMSystems have a lower hardware cost per kit.
- Lower cost per Sensor failure event.
- Lower overall total cost of ownership even before factoring in safety incident costs.

13.6 Fleet-Level Benefits.

- Higher fleet availability and utilisation.
- Better tyre life due to continuous monitoring and reduced unattended failures and quick Sensor replacement.
- Lower pyrolysis and tyre- fire risk.
- Consistency of TMSystem technology across various vehicle types.

13.7 Accuracy.

- Pressure accuracy is essentially identical between TyreGuard® and Internal Sensors (±1- 2 psi).
- Temperature accuracy is functionally equivalent for alarm and trend purposes.

13.8 Serviceability.

- Internal Sensors that require full tyre removal for replacement, producing major safety risk, downtime, and cost.
- External Sensors (TyreGuard®) that can be replaced in minutes without tyre removal, greatly reducing risk and cost.

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13.9 Safety Risk

- Internal Sensors exposes technicians to high- risk tyre operations for every Sensor event.
- External Sensors eliminates the need for dangerous tyre- handling purely for TMSystem maintenance.

13.10 Hardware Cost.

- Each Internal Sensors failure event for an ultra- class truck can cost \$800 / \$1,500 or more.
- Each TyreGuard® External Sensor event is approximately A\$400- \$500.
- On a single 6 x Wheel Truck, 5 x year replacement of ALL Internal Sensors would be \$4,800- \$9,000 for a TMSystem with External Sensors (TyreGuard®) would be \$2,400- \$3,000.
- On a single 6 x Wheel Truck, a single SRE (failed Sensors) every year for 5 x years would calculate to for Internal Sensors \$4,000- \$7,500 compared to External Sensors of \$2,000- \$2,500.
- Now considering a fleet of 20 x **Trucks over 5 years** the comparative costs calculate to:
 - **Internal Sensors:** \$176,000- \$330,000.
 - **External Sensors:** \$88,000- \$110,000

13.11 Production Downtime.

Estimated or calculated costs may substantially increase total losses when internal sensors are taken into account, considering the following:

- **Sensor lifespan:** Internal sensors may not last the full five years and require more frequent replacement.
- **Failure frequency:** More than one sensor failure per truck per year may occur.
- **Unscheduled failures:** SRE failures are often unpredictable. Even when replacements are planned, the production losses associated with tyre disassembly, reassembly, and handling must still be considered.
- **Additional production impacts:** Further production losses may arise depending on product tonnage (\$\$/ ton) and hours affected.
- **Off-site tyre exchanges:** Some sites require tyres to be exchanged off-site, resulting in additional downtime and production loss, as well as transport costs for sending and returning tyres for every internal sensor replacement.

14. CONCLUSION

External Sensors (TyreGuard®) are the safer, lower- cost, and operationally superior TMSystem for mining fleets compared with internal- Sensor systems.

The decisive advantages arise from the External Sensor architecture, which removes the need for tyre removal when servicing the TMSystem, while maintaining equivalent pressure accuracy and effective temperature monitoring.

The whole of life costs for Internal Sensors is clearly apparent when considering the replacement cost and most significantly the down- time (scheduled or unscheduled) / production loss required for Sensor replacement.

More information and links to compliance guidelines, news articles, etc, can be found at these references to our web site sections

- [LSM TyreGuard® TMSystems.](#)
- [Links and References.](#)

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