THE TMM DIGITAL TWIN
A customized trackless mobile machinery collision prevention system

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Presentation outline

- Background
- TMM CPS Digital Twin: Objective Focus
- TMM Digital Twin: Data Modelling & Simulation Capabilities
Background

Since November 2020 there has been extensive engagements between the Minerals Council and the CSIR to investigate the art of the possible regarding the following:

- To support the elimination of transport fatalities in support of Zero Harm — transport related incidents have been amongst the top three causes of fatalities and injuries in the SAMI over the past decade.

- Efficient operations of Trackless Mobile Machinery (TMM) across the mining sector — SA mining companies are producing at high cost and need to improve efficiencies & productivity to reduce costs.

- Locally produced Collision Prevention Systems (CPS) — SA has been implementing international CPS systems, with high cost of installation, maintenance and product life cycle.

![Fatality by causes: 2000-2021](source: Department of Mineral Resources and Energy)

- 7 TMM related fatalities out of 69 total fatalities recorded during 2021
- 6 (15%) TMM related fatalities out of 42 total fatalities recorded during the period 01 Jan-31 Oct 2022
TMM CPS Digital Twin: Objective Focus

- Predicting and detecting unsafe acts and conditions, allowing the mine to timeously implement corrective actions to prevent potential TMM accidents.
- Near real time, continuous safety risk management tool: to assess and improve the effectiveness of the vehicle interaction controls.
- Continuously and proactively identify high risk areas and activities per shift, including assessing and quantifying the different levels of risks within the traffic management system.
- Providing a standardized safety risk assessment and quantification tool, in support of progressive safety improvement in the mining sector.
- Optimising the traffic management system in terms of safety, including productivity and efficiencies to drive down cost.
- Supporting progressive, sustainable and people-centric modernization of the mining sector (hence growth and improved contribution of the mining sector to the socio-economic development of South Africa).

Strategic approach for the TMM CPS digital twin development

**Phase 1**
Development of VI Collision avoidance Digital Twin
- Define application of Digital twin technology
- Engagement with industry and secure partnerships
- Development of risk based tool to prevent Vehicle collision
- CSIR Capability development

**Phase 2**
Develop Integrated Decision support tool
- Migration of tool to a "Cloud based" platform
- Application of Risk based tool by the Mining Industry
- Establishment of further industry requirements e.g. Carbon emissions
- Development of value adding features to the tool

**Phase 3**
Support Localised Autonomous systems
- Develop an industry assessment tool, to determine, assess and support relevant adoption of Autonomous systems
- Support development of localised autonomous systems e.g. Sensor development
- Local support and training for Mining Autonomous based systems
The TMM Digital Twin: Introduction of Solution

A Digital Twin is a virtual representation/models of processes that define the performance of the physical/original machine.
TMM Digital Twin: Problem Space

Traffic Management Plan
- CREATION
- IMPLEMENTATION
- EVENT MONITORING
- INCIDENT RESPONSE

Qualitative/Subjective Risk Assessment
- Historic Data & Operational Experience

Reactive Intervention
TMM Digital Twin: Solution Space

Traffic Management Plan
- Creation
- Implementation
- Incident Response
- Event Monitoring
Traffic Management Plan

**CREATION**

**IMPLEMENTATION**

**EVENT MONITORING**

**EVENT RESPONSE**

Qualitative
Historic Data & Operational Experience

Quantitative

Predictive
Risk Identification

Digital Twin Modelling Framework

TMM Digital Twin: Solution Space
TMM Digital Twin: Technical Processes

Historical Data

Data Analytics

Machine Learning

Recommendations

Predictions

Pro-active interventions
TMM Digital Twin: Risk Identification and Mitigation

Qualitative

Historic Data & Operational Experience

“Leading Practice Elements”
TMM Digital Twin: Risk Identification and Mitigation

Data Analytics & Modelling

Digitalization

Quantitative

Digital Twin Creation
TMM Digital Twin: Simulation Components

**Vehicle Logs**
Longitude, Latitude
Vehicle Log Data
Vehicle Interactions

**Operational Practices**
Risk Based Management & Analysis

**Traffic Management Plan (TMP)**
Leading Safety Practices

**Digital Twin Simulation Core**
Data Analytics, Machine Learning

**Digitalization**
TMM Digital Twin: Simulation Core - Capabilities

01
Sensor Technology Modelling

02
Vehicle Technology Modelling

Digital Twin Technology

Micro-environment around TMMs
(Vehicle interaction dynamics, Vehicle sensors)

RISK MANAGEMENT
TMM Technologies

Vehicle Log Data – Longitude, Latitude
TMM Digital Twin: Simulation Core - Capabilities

Macro-environment around the vehicle
(Multi-Vehicle Interaction Scenarios)
TMM Digital Twin: Simulation Core - Capabilities

Digital Twin Technology

05 Statistical & Machine Learning

06 Modelling & Simulation As-a-Service

RISK MANAGEMENT

TMM Technologies
TMM Digital Twin: Simulation of Vehicle Speeds
TMM Digital Twin: Loading / Unloading Events
TMM Digital Twin: Simulation of TMP
## Risk Identification: Unsafe Conditions captured by Digital Twin

<table>
<thead>
<tr>
<th>Vehicle Interaction</th>
<th>![Vehicle Interaction Diagram]</th>
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<tbody>
<tr>
<td>Anomaly events</td>
<td>![Anomaly Events Diagram]</td>
</tr>
<tr>
<td>Conformance/Non-conformance events</td>
<td>![Conformance/Non-conformance Events Diagram]</td>
</tr>
</tbody>
</table>
Risk Identification: Unsafe Conditions - Vehicle Interactions
Risk Identification: Unsafe Conditions – Anomaly Detection

"Anomaly Event" - Detection
Risk Identification: Unsafe Conditions – Non-Conformance

- Speed violation
- Stop violation
- Berm zone
- Speed zone
- Berm/Distance violation
- Stop zone
TMM Digital Twin: Process Optimization Cycle

“Real World” environment

Data Analysis

“Digital Twin” environment

“Machine Learning” Model
### Compliance Benefits

Improved TMM safety and compliance:
- Ensuring that sufficient controls are in place to prevent undesirable TMM interactions / accidents.
- Flexibility to respond to changes without compromising safety and compliance.

### Strategic Benefits

Dynamic traffic management provides:
- Predicting the performance of traffic management systems in terms of safety, productivity, and costs, thus providing input into short-medium-long term planning for greenfield & brownfield projects.
- Data-driven insights to enable continuous improvement of TMM safety, productivity, and cost reduction.

### Operational Benefits

Improve safety and maintain efficient production by:
- Predicting / detecting unsafe acts and conditions, allowing subsequent implementation of appropriate corrective actions (e.g. training and behavior change interventions to reduce unsafe acts).
- Increased focus on proactive and predictive risk management, including ability to continuously identify high-risk areas within the traffic management system.

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**PROFILE A**

- **Speed Violations**
- **Stop Violations**
- **Berm Violations**
- **Harsh Braking**

Conformance chart:
- Speed Violations
- Stop Violations
- Berm Violations
- Harsh Braking
Conclusions

• Phase 1 demonstrated that the TMM CPS digital twin can be utilised as tool for:
  o Predicting the performance of a traffic management system in terms of parameters such as safety, productivity and costs.
  o Continuous assessment of TMM collision risks.
  o Detecting and predicting unsafe acts.

• We are currently conducting an operational pilot at an open cast coal mine in the Limpopo Province, as part of Phase 2.

• Lessons learnt from the pilot will be shared with the industry (with the permission of the pilot mine).
THANK YOU