The TMM Digital Twin: Strategic Objective

To provide mining houses with a close-to real-time risk profiling and productivity tool that takes an objective approach to assessing risks based on the Mine Health and Safety regulations (Act no. 29 of 1996 – clause 8.10)
TMM Digital Twin: Problem Space

Traffic Management Plan CREATION

Traffic Management Plan IMPLEMENTATION

Traffic Management Plan EVENT MONITORING

Traffic Management Plan INCIDENT RESPONSE

Reactive Intervention

Qualitative/Subjective Risk Assessment
Historic Data & Operational Experience
TMM Digital Twin: Solution Space

**Qualitative**
Historic Data & Operational Experience

**Quantitative**
Risk Identification

**Predictive**
Risk Identification

Digital Twin Modelling Framework
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**

<table>
<thead>
<tr>
<th>Consequence Level</th>
<th>Insignificant</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Major</th>
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<tr>
<td>Almost Certain</td>
<td>11 (M)</td>
<td>16 (S)</td>
<td>20 (S)</td>
<td>23 (H)</td>
<td>26 (H)</td>
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<tr>
<td>Likely</td>
<td>7 (M)</td>
<td>12 (M)</td>
<td>17 (S)</td>
<td>21 (H)</td>
<td>24 (H)</td>
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<td>Possible</td>
<td>4 (L)</td>
<td>8 (M)</td>
<td>13 (S)</td>
<td>18 (S)</td>
<td>22 (H)</td>
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<td>Unlikely</td>
<td>2 (L)</td>
<td>5 (L)</td>
<td>9 (M)</td>
<td>14 (S)</td>
<td>19 (S)</td>
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<tr>
<td>Rare</td>
<td>1 (L)</td>
<td>3 (L)</td>
<td>6 (M)</td>
<td>10 (M)</td>
<td>15 (S)</td>
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</table>

"Leading Practice Elements"
TMM Digital Twin: Risk Identification and Mitigation

Digitalization

Data Analytics & Modelling

Quantitative

Digital Twin Creation
TMM Digital Twin: Simulation Components

**VEHICLE LOGS**
Longitude, Latitude
Vehicle Log Data
Vehicle Interactions

**TRAFFIC MANAGEMENT PLAN (TMP)**
Leading Safety Practices

**OPERATIONAL PRACTICES**
Risk Based Management & Analysis

**DIGITAL TWIN SIMULATION CORE**
Data Analytics, Machine Learning

Digitalization
TMM Digital Twin: Simulation Core - Capabilities

- **01** Sensor Technology Modelling
- **02** Vehicle Technology Modelling
- **03** Mine Layout & Geographical Modelling
- **04** Mine Traffic Management Modelling
- **05** Statistical & Machine Learning
- **06** Modelling & Simulation As-a-Service

**Digital Twin Technology**

**RISK MANAGEMENT Technologies**
Data Insights around vehicle movement

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

Macro-environment around the vehicle
(Multi-Vehicle Interaction Scenarios)

01 Sensor Technology Modelling
02 Vehicle Technology Modelling
03 Mine Layout & Geographical Modelling
04 Mine Traffic Management Modelling
05 Statistical & Machine Learning
06 Modelling & Simulation As-a-Service

Digital Twin Technology

RISK MANAGEMENT Technologies
TMM Digital Twin: L1 – L9

**Level 1:** Site Requirements

**Level 2:** Segregation Controls

**Level 3:** Operating Procedures

**Level 4:** Authority to Operate

**Level 5:** Fitness to Operate

**Level 6:** Operating Compliance

**Level 7:** Operator Awareness

**Level 8:** Advisory Controls

**Level 9:** Intervention Controls

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**Work Area Controls** for all equipment that could reduce "Significant Risk" and costs

**“Residual Risk” Management**

Regulation 8.10.1 and 8.10.2

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EMESRT (Earth Moving Equipment Safety Round Table) framework

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**Regulation 8.10.2**

8.10.2.1 Every diesel powered trackless mobile machine must be provided with means to automatically detect the presence of any other diesel powered trackless mobile machine within its vicinity, and

8.10.2.1(a) upon detecting the presence of another diesel powered trackless mobile machine, the operators of both diesel powered trackless mobile machines shall be warned of each other’s presence by means of an effective warning, and

8.10.2.1(b) in the event where no action is taken to prevent potential collision, further means shall be provided to retard the diesel powered trackless mobile machine to a safe speed where after the brakes of the diesel powered trackless mobile machine are automatically applied. The prevent potential collision system on the diesel powered trackless mobile machine must "fail to safe" without human intervention.
Risk Identification: Unsafe Conditions captured by Digital Twin

Vehicle Interaction

Conformance/Non-conformance events

Anomaly events
TMM Digital Twin: Vehicle Interaction Events

Level 1: Site Requirements
Level 2: Segregation Controls
Level 3: Operating Procedures

Vehicle Interaction Events
Inference of Vehicle Interaction Events using only the GPS data

Simulated Heatmap (Detection Radius 5m)

Simulated Heatmap (Detection Radius 10m)

Layout: GPS Data

Vehicle Interaction Events

TMM Digital Twin: Vehicle Interaction Events
TMM Digital Twin: Conformance/Non-Conformance

Level 1: Site Requirements
Level 2: Segregation Controls
Level 3: Operating Procedures
Level 4: Authority to Operate
Level 5: Fitness to Operate
Level 6: Operating Compliance

Vehicle Interaction Events

Conformance / Non-Conformance
Risk Identification: Unsafe Conditions – Non-Conformance

- Stop violation
- Speed exceeded
- Berm violation

Conformance / Non-Conformance

- Speed zone
- Berm zone
- Stop zone
Risk Identification: Unsafe Conditions – Non-Conformance

- Speed violation
- Berm/Distance violation
- Stop violation
Risk Identification: Unsafe Conditions – Anomaly Detection
TMM Digital Twin: Truck Routes
TMM Digital Twin: Driver Behaviour Analytics

Operator Profile
- Work schedule
- Operator experience
- Class of vehicle

Driver Score
Accumulative score based on operator profile and site performance
TMM Digital Twin: Process Optimization Cycle

"Real World" environment

Data Analysis

"Digital Twin" environment

"Machine Learning" Model
TMM Digital Twin: Product Roadmap

Provide locally developed solution (mining and industry at large)

Digital Platform
Monitor, assess and prevent unwanted events

Integrated Decision Support System
Safety & productivity (costs, TMM status & emissions)

Mine Enterprise System

Digital Twin Tool
Continuous technological and commercial Development

CSIR Capability Development