

# CSIR TMM Collision Prevention Digital Twin

CSIR operational pilot conducted at an open pit operation in South Africa

**MCSA – Multidisciplinary Technical Expert Committee**

31 August 2023

# TMM Collision Prevention Digital Twin: History



## “The Art of the Possible”:

- Support Zero Harm
- Productivity
- Localization

Mining Operators

“The Art of the Possible”

Technology  
OEM & OTM

Mine Health and Safety Act, 1996 (Act No. 29 of 1996) and Regulations

### Regulations

#### Collisions between trackless mobile machines and pedestrians

##### 8.10.

- (1) The *employer* must take *reasonably practicable* measures to ensure that pedestrians are prevented from being injured as a result of collisions between trackless mobile machines and pedestrians. At any mine where there is a significant risk of such collisions, such measures must include at least the following:



# CSIR TMM Digital Twin: Strategic Objective

To provide mining houses with a near 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)



# CSIR Operational Pilot: Value Add Elements

## Data Inputs

Traffic Management Plan

Vehicle Logs

Historical Data & Knowledge

TMM Digital Twin  
Data Analytics

TMM Digital Twin  
Framework

TMM Digital Twin  
Simulation  
Frameworks

## Data output and analysis

Non-conformance  
Events

Anomaly Events

Vehicle  
Interaction Events

# CSIR Operational Pilot: 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

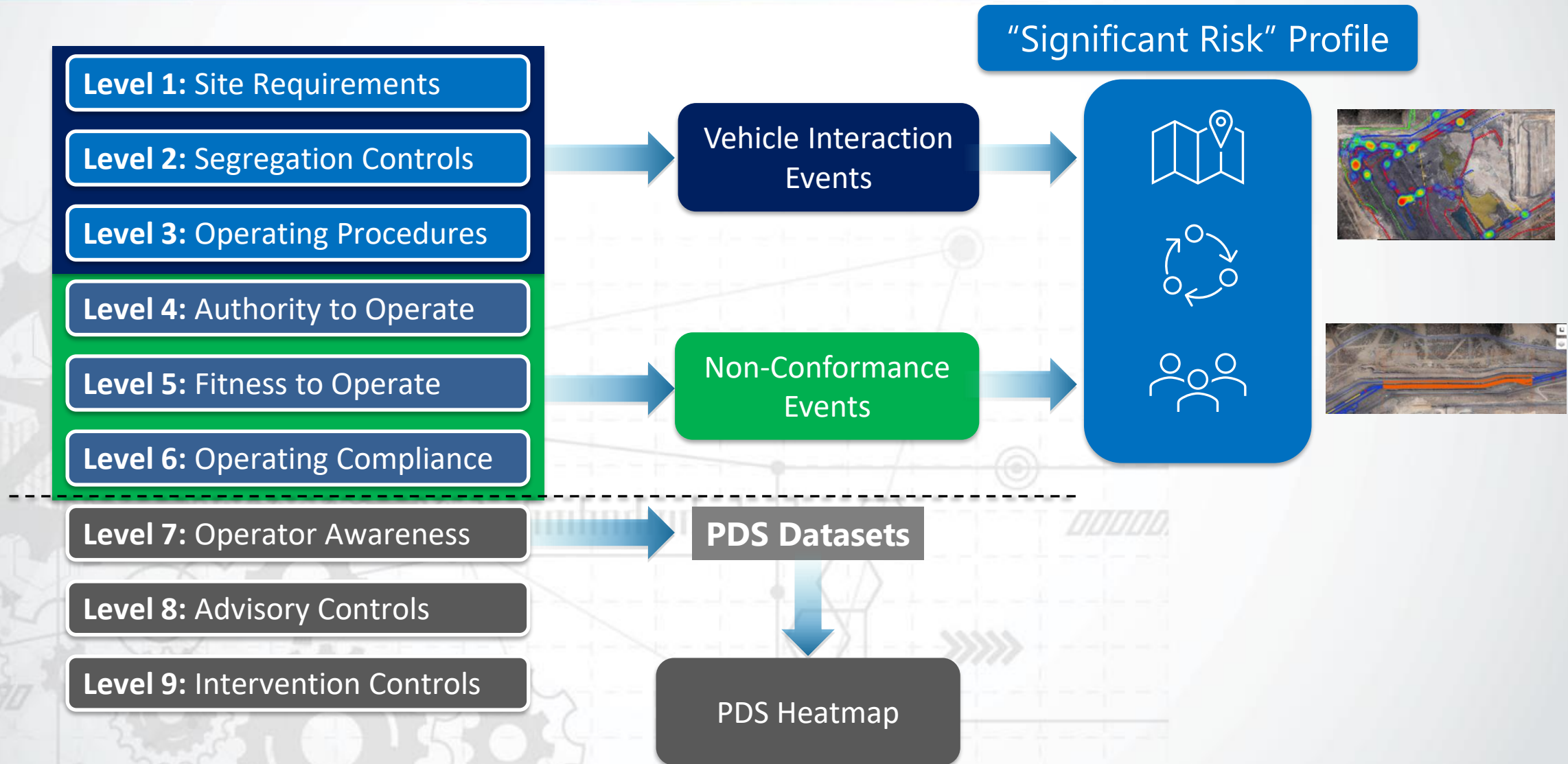
**Work Area Controls** for all equipment that could reduce **“Significant Risk”** and costs

How can we help the mine to qualify & **quantify** that their L1-L6 are implemented Effectively / Efficiently

**“Residual Risk”**  
Management

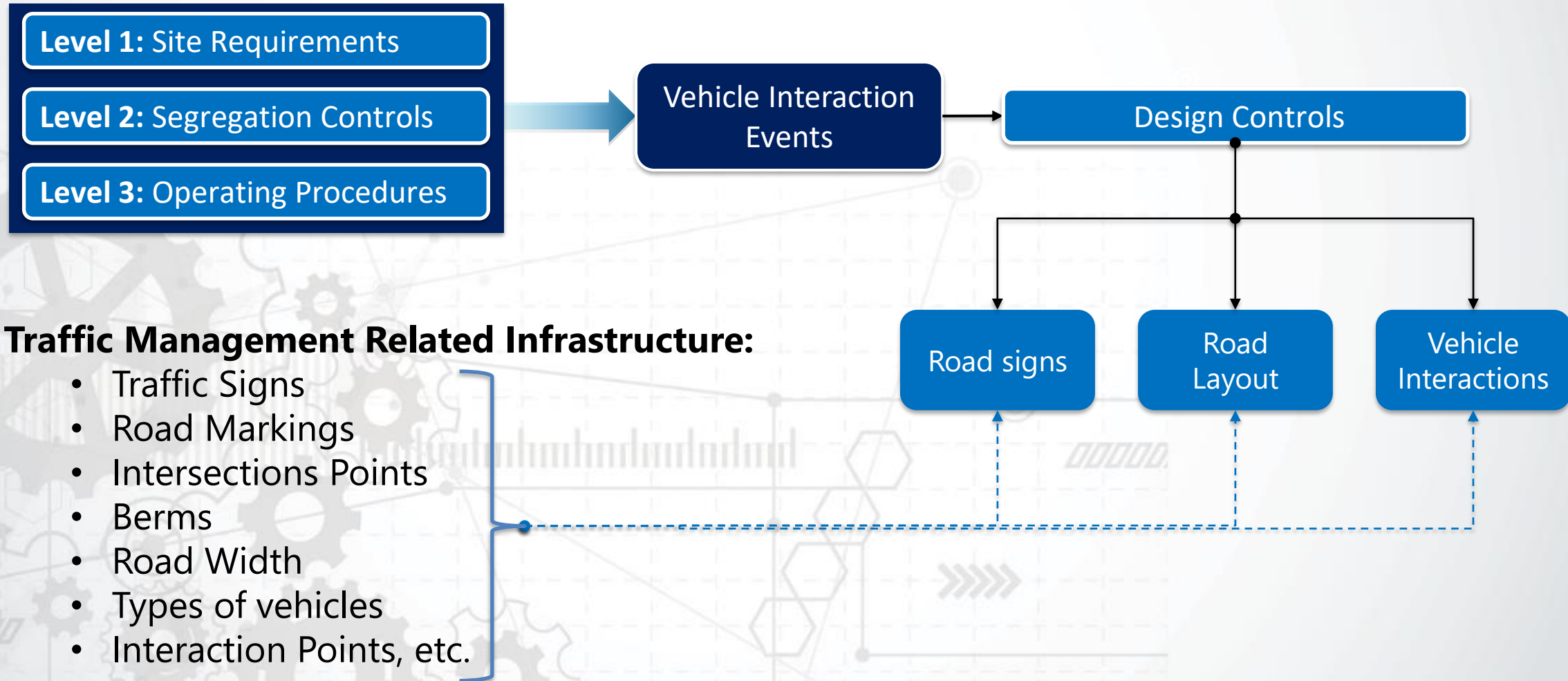
Regulation 8.10.1 and 8.10.2

# CSIR Operational Pilot: L1 – L9 Application

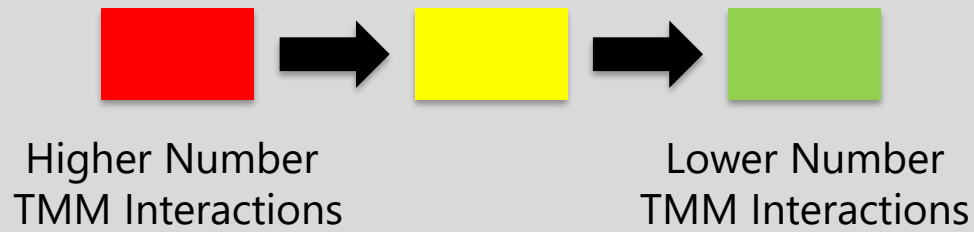


# CSIR Operational Pilot: Vehicle Interaction Events Analysis

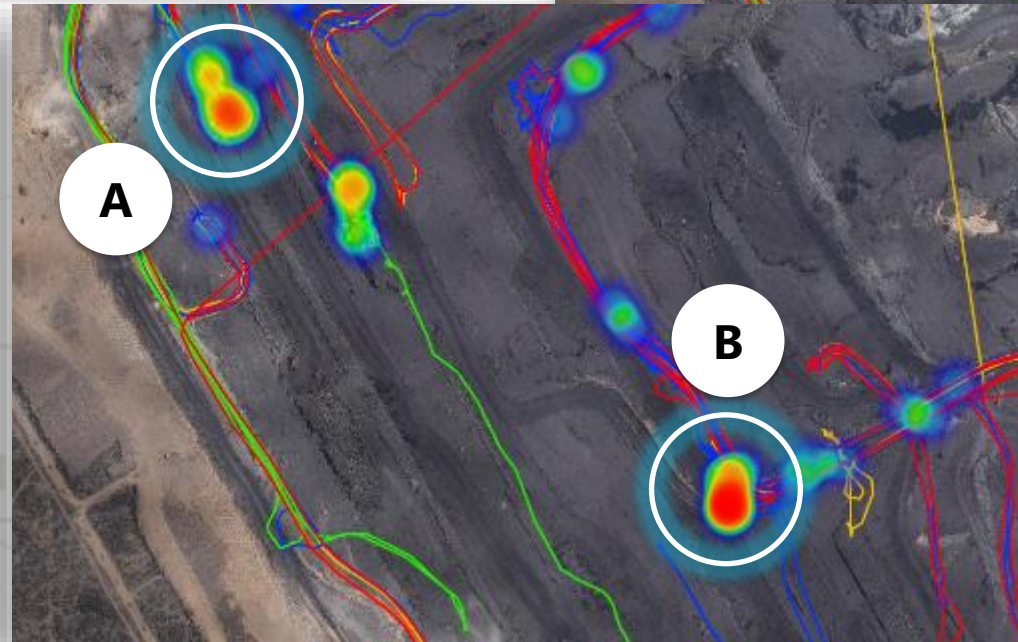
## EMESRT Level 1 to 3 of Intervention Controls



# CSIR Operational Pilot: Vehicle Interaction Events (Example)



**8** Simulated Heatmap  
(Detection Radius 5m)



Simulated Heatmap  
(Detection Radius 10m)



Layout: GPS Data



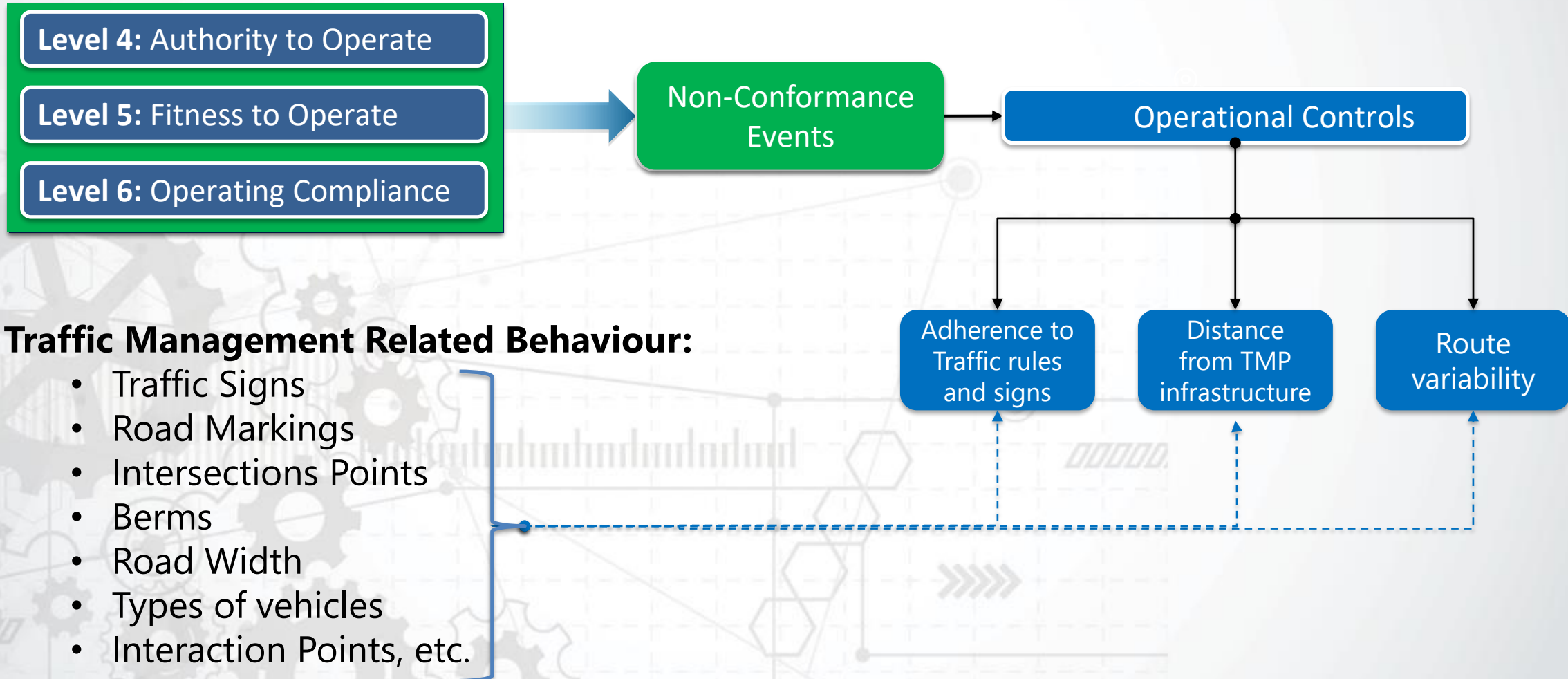
Detection



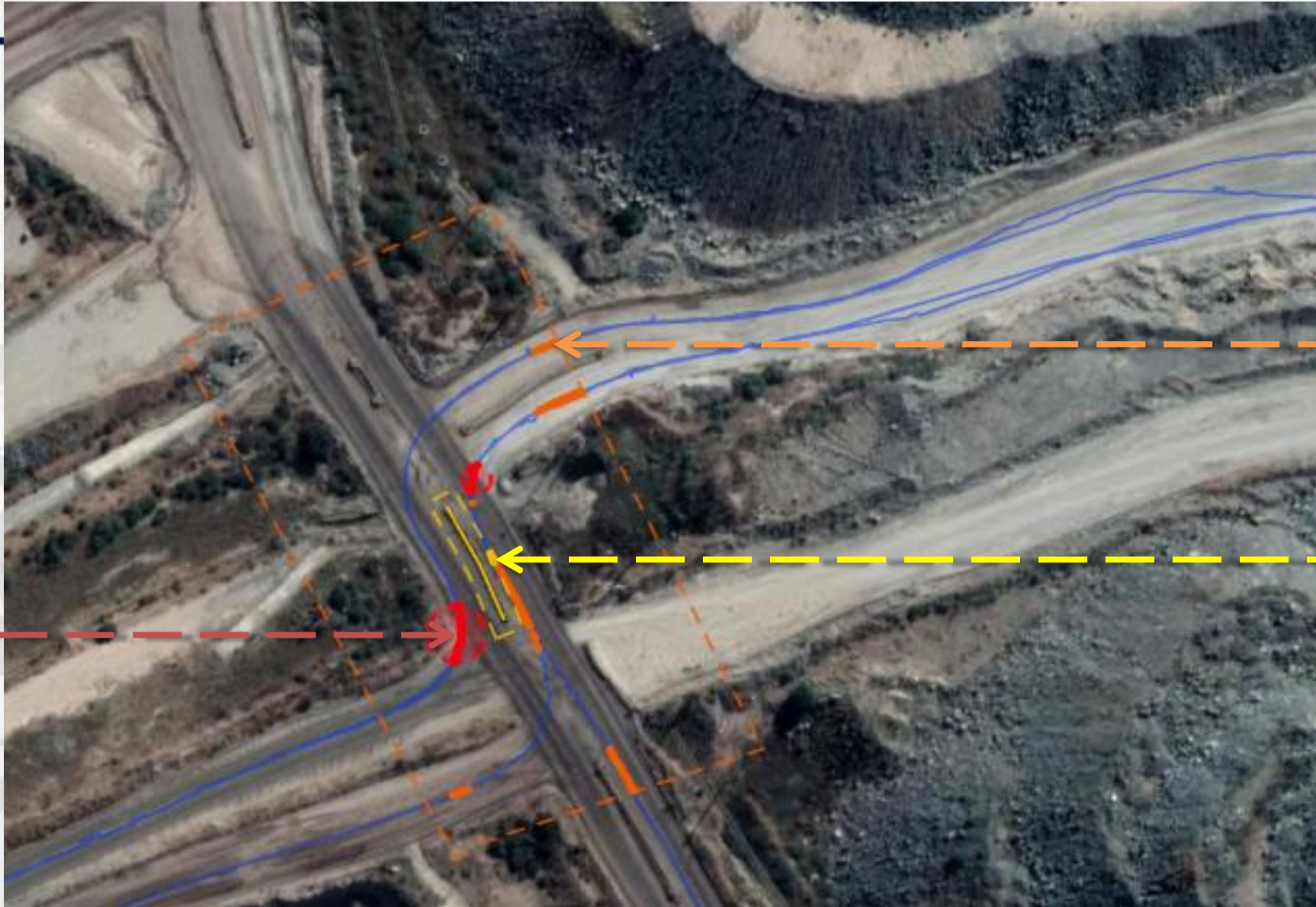


# CSIR Operational Pilot: Non-Conformance Events Analysis

## EMESRT Level 4 to 6 of Intervention Controls



# CSIR Operational Pilot : Non-Conformance Detection (Example)



Speed violation

Berm/Distance violation

Stop violation

# CSIR Operational Pilot: Non-Conformance Analysis for Pilot Site

## Data set information

- All vehicle types considered and grouped:
  - Haul trucks only
  - Light vehicles only
  - All other vehicles

## Rules considered for analysis

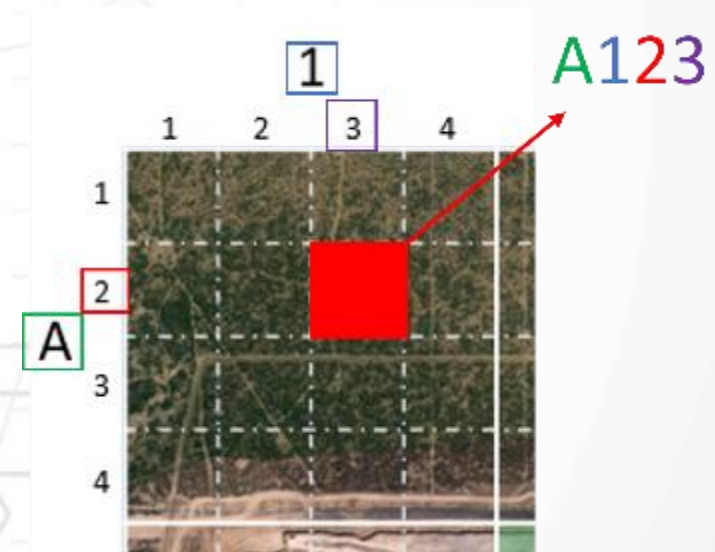
- Traffic management plan
- Operating practice instructions

## Non-conformances tracked

- Berm violations
- Speed violations
- Stop sign violations

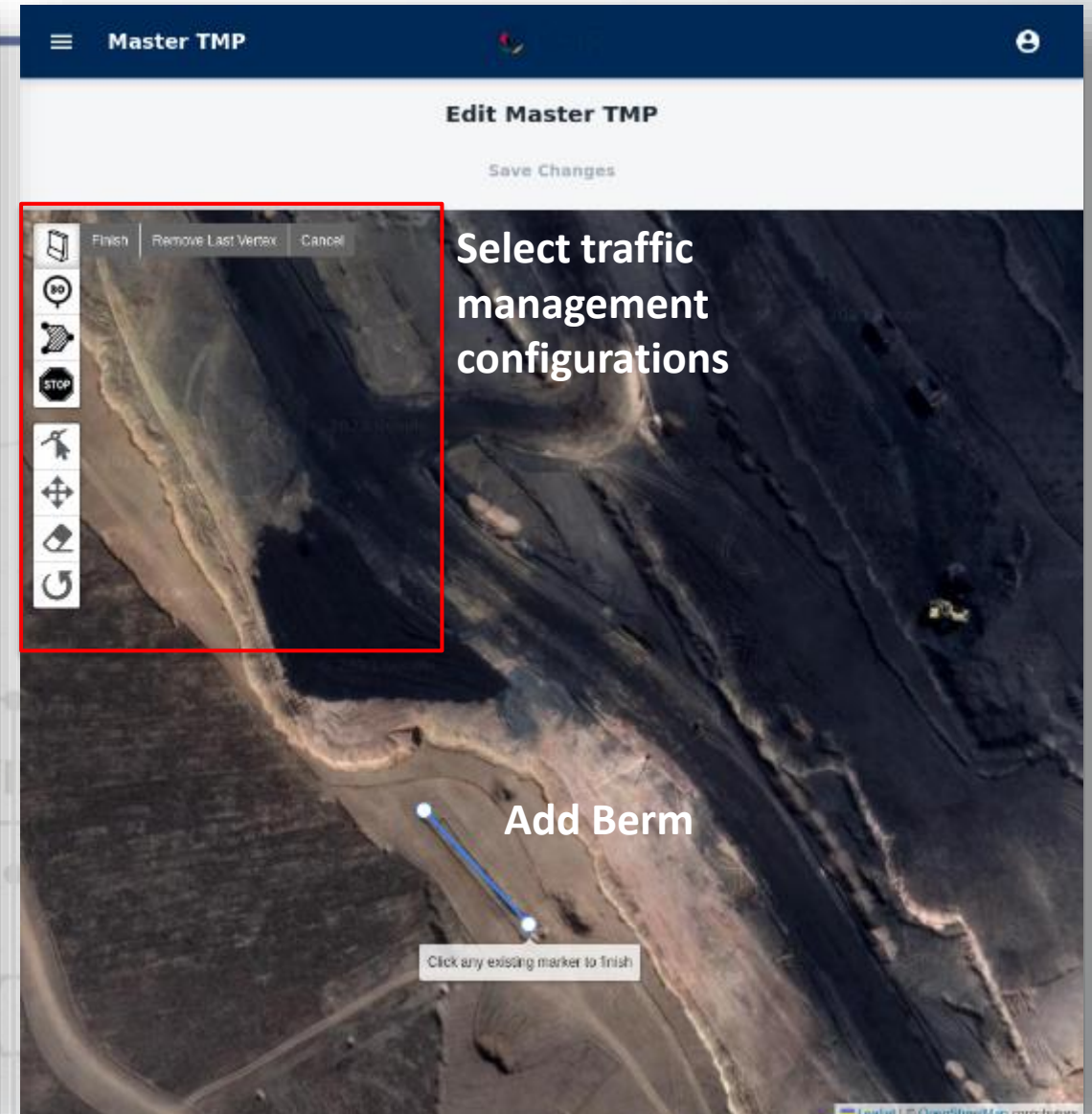
## Sectored grid

- Major sectors
- Minor sectors



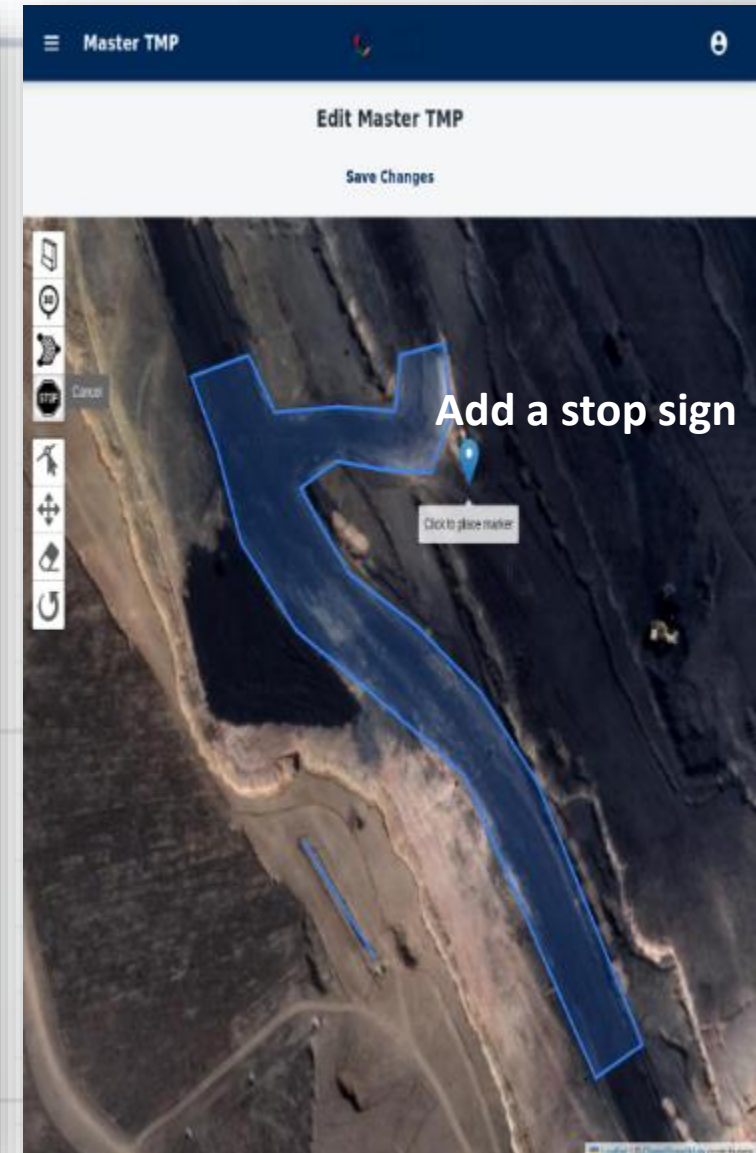
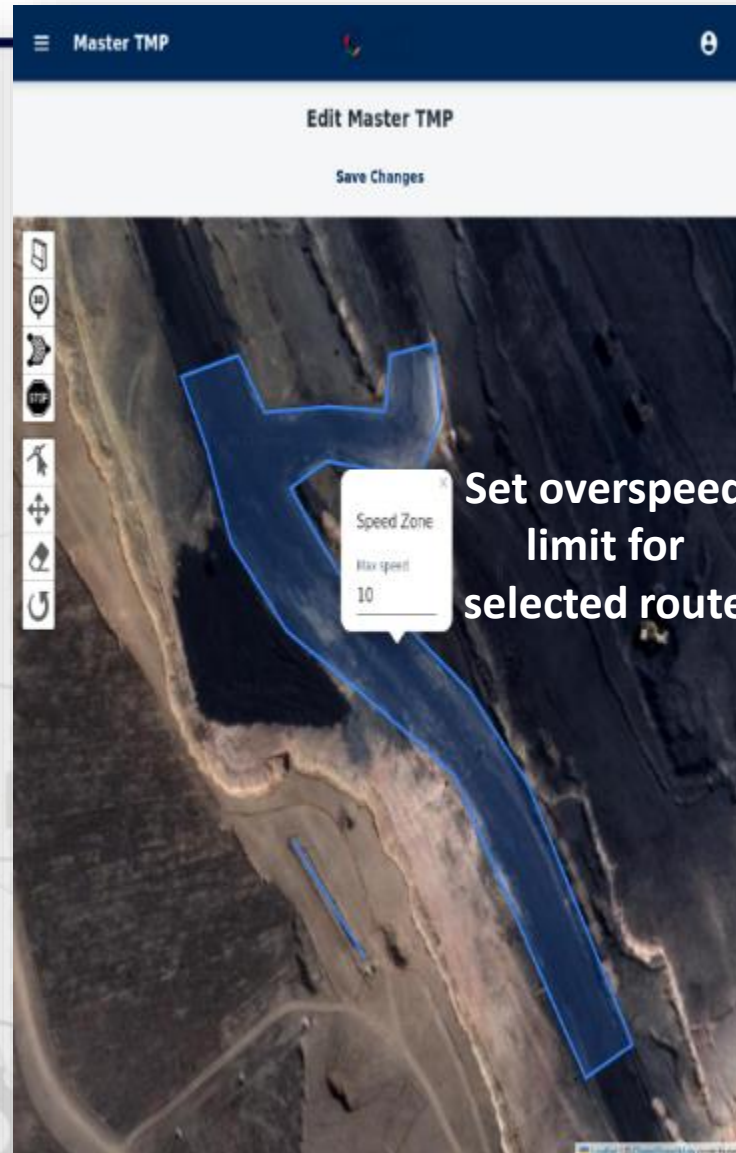
# CSIR Operational Pilot: TMP Setup

Non-Conformance  
Analysis

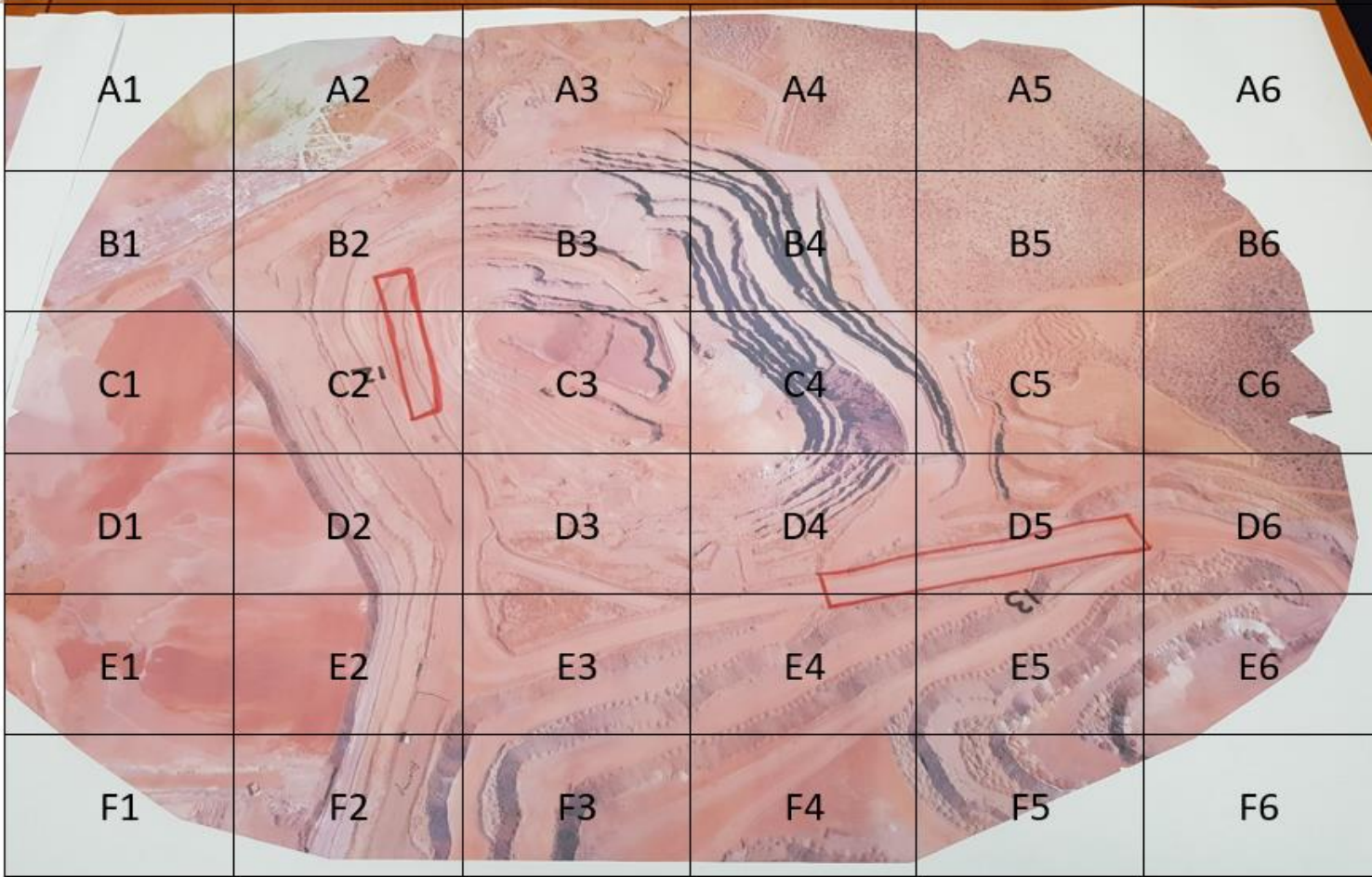


# CSIR Operational Pilot: TMP Setup

Non-Conformance Analysis



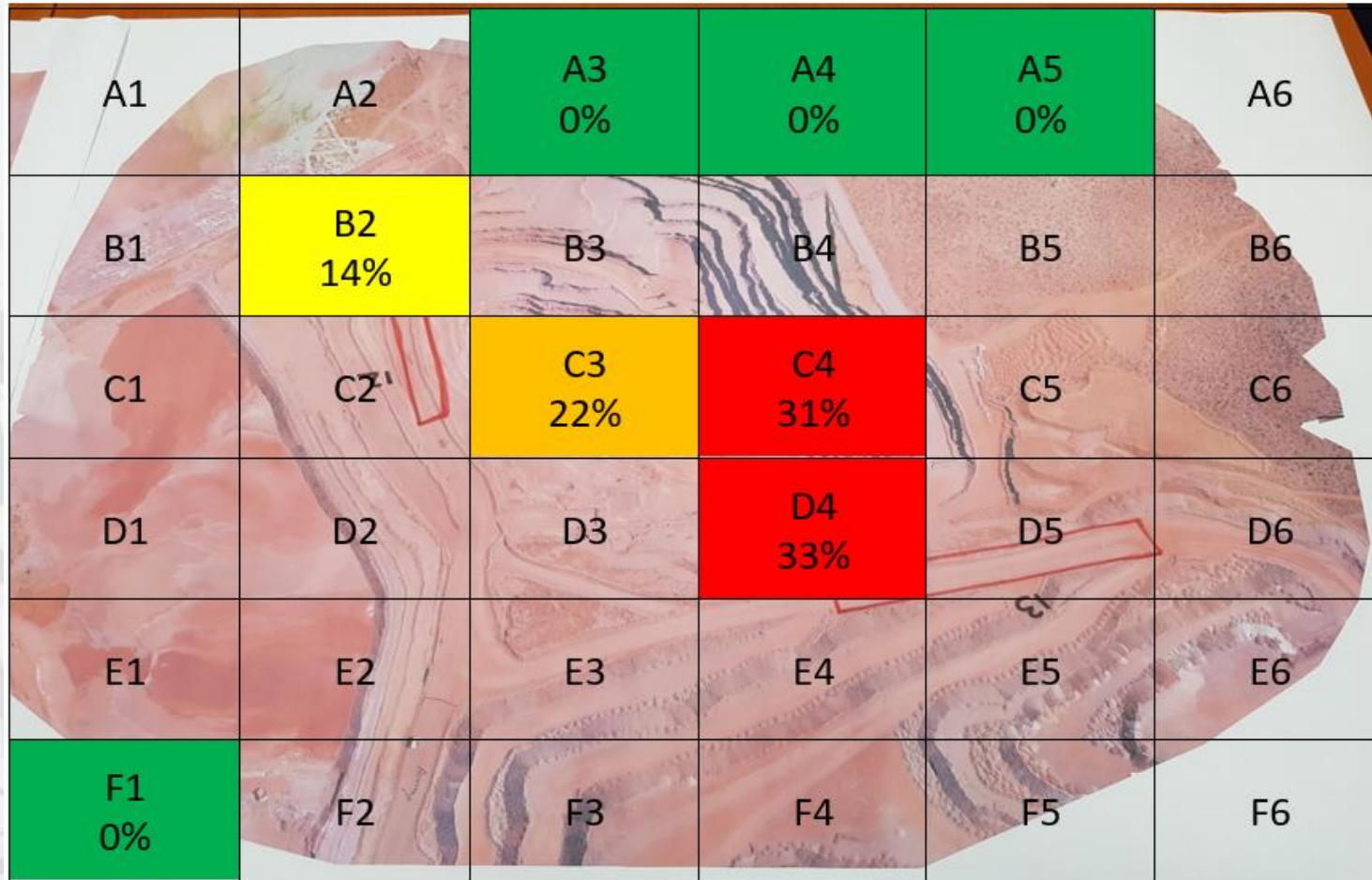
# CSIR Operational Pilot: Typical Layout Grid for Analyses



Mine layout described as a sector grid, A1 to F6

**Important note:** Actual operational data is not shared due to data privacy

# CSIR Operational Pilot: Typical Statistical Analysis of Non-Conformance



| Infringement level |        |
|--------------------|--------|
| Very High          | Red    |
| High               | Orange |
| Medium             | Yellow |
| Low                | Green  |

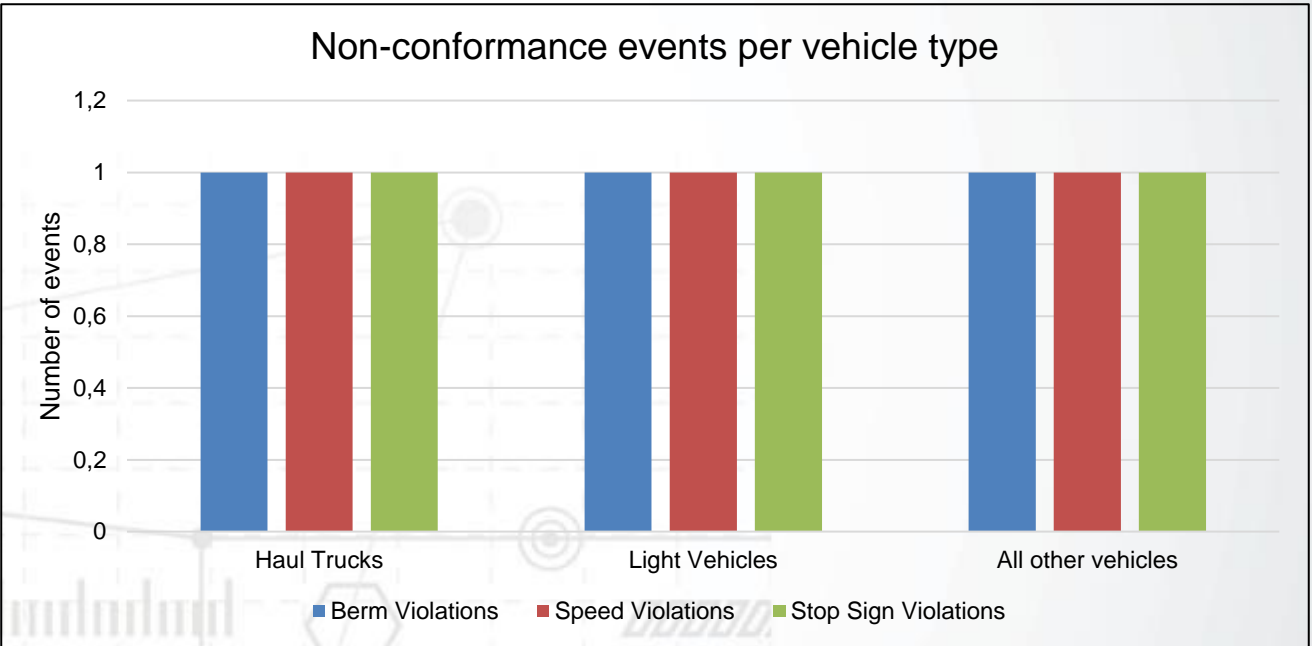
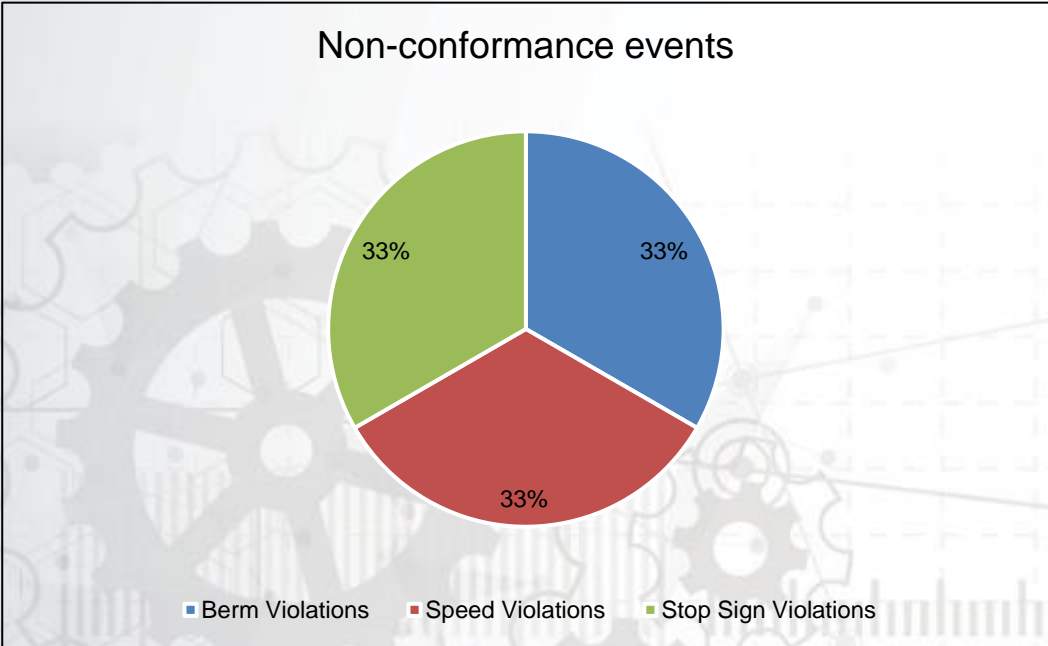
## Violations displayed

- Speed violations
- Berm violations
- Stop sign violations

## Statistics displayed

- Percentage of infringements in each sector
- Colour grade based on percentage

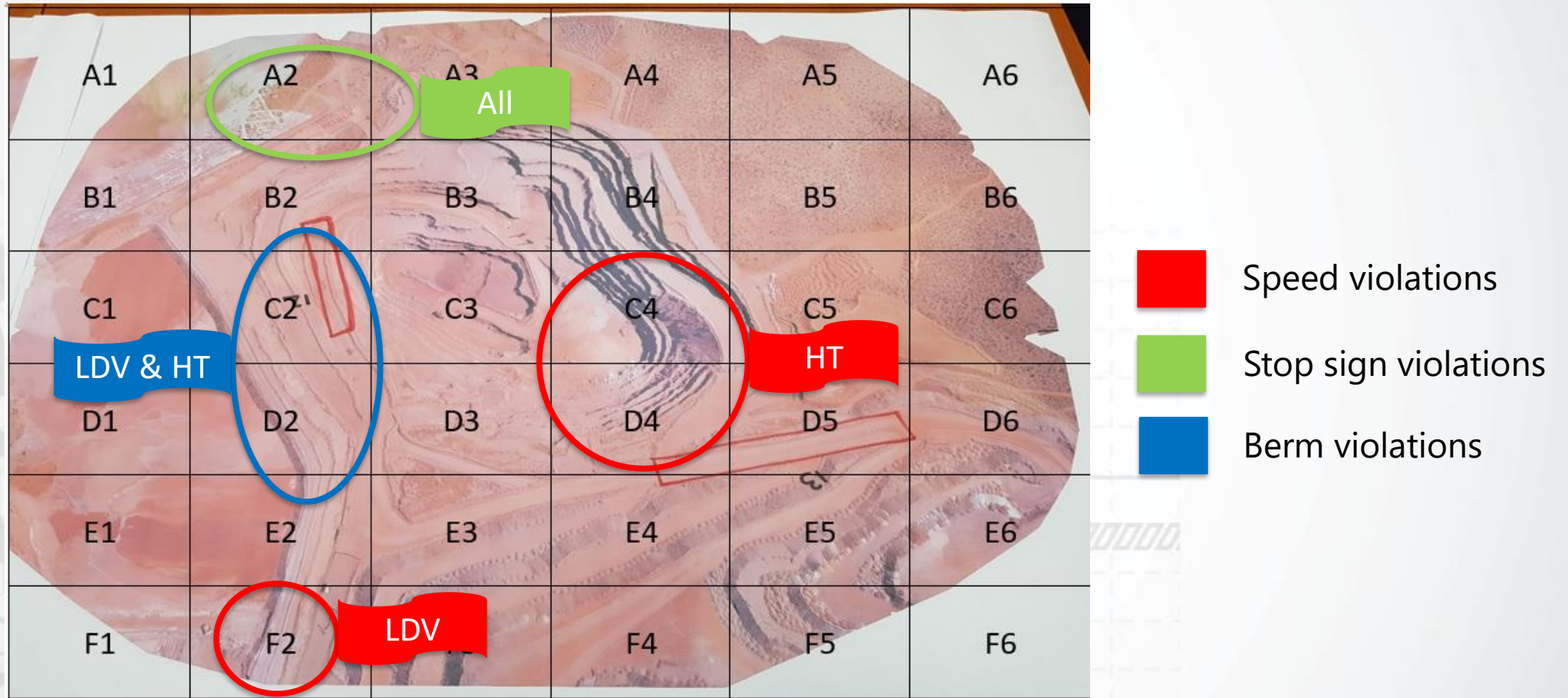
# CSIR Operational Pilot: Non-Conformance Events Summary



**Important note:** Actual operational data is not shared due to data privacy



# CSIR Operational Pilot: Typical Non-Conformance Analysis – Areas of Interest



**Important note:** Actual operational data is not shared due to data privacy

# CSIR Operational Pilot: Vehicle Interaction Analysis for Pilot Site

## Vehicles interaction information

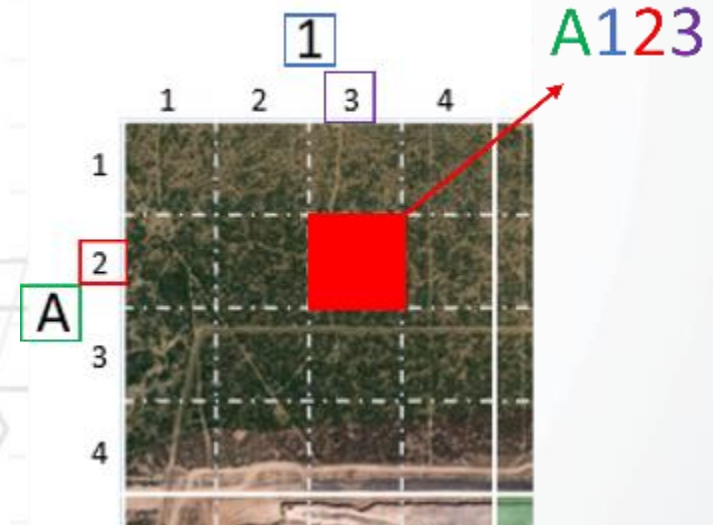
- All vehicle types considered and grouped:
  - Haul trucks only
  - Haul trucks and Light vehicles
  - Haul trucks, shovels & frontend loaders
  - Haul trucks, water bowsers, graders & dozers

## Rules considered for analysis

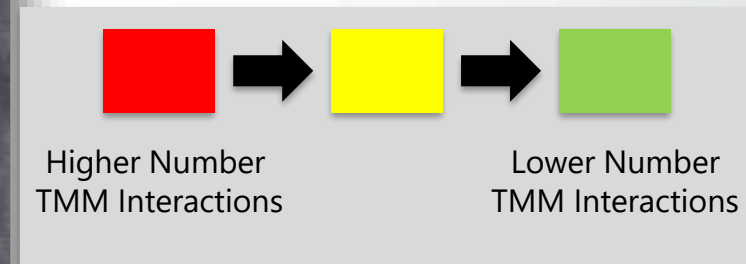
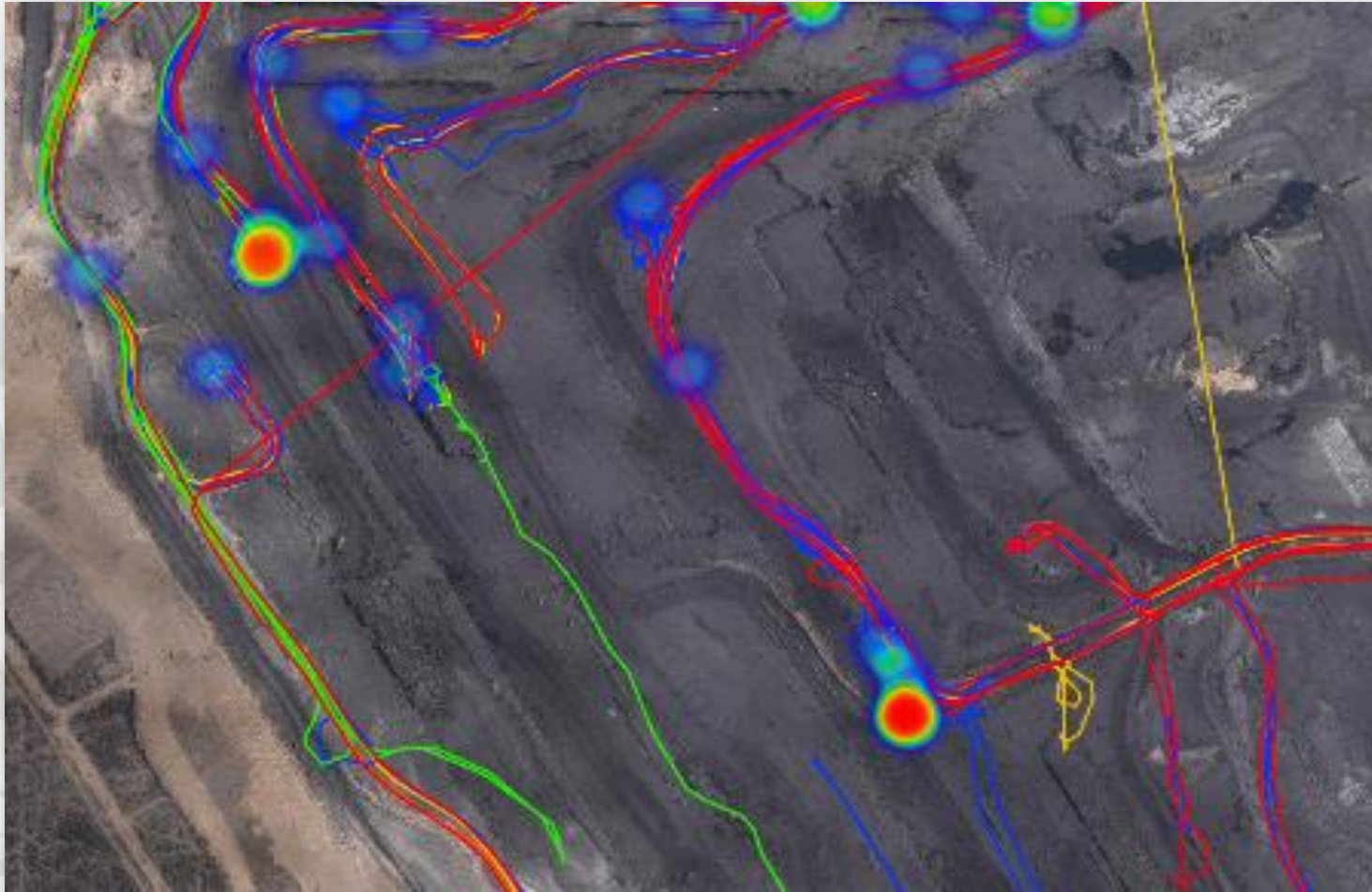
- Operating practice instructions

## Sectored grid

- Major sectors
- Minor sectors

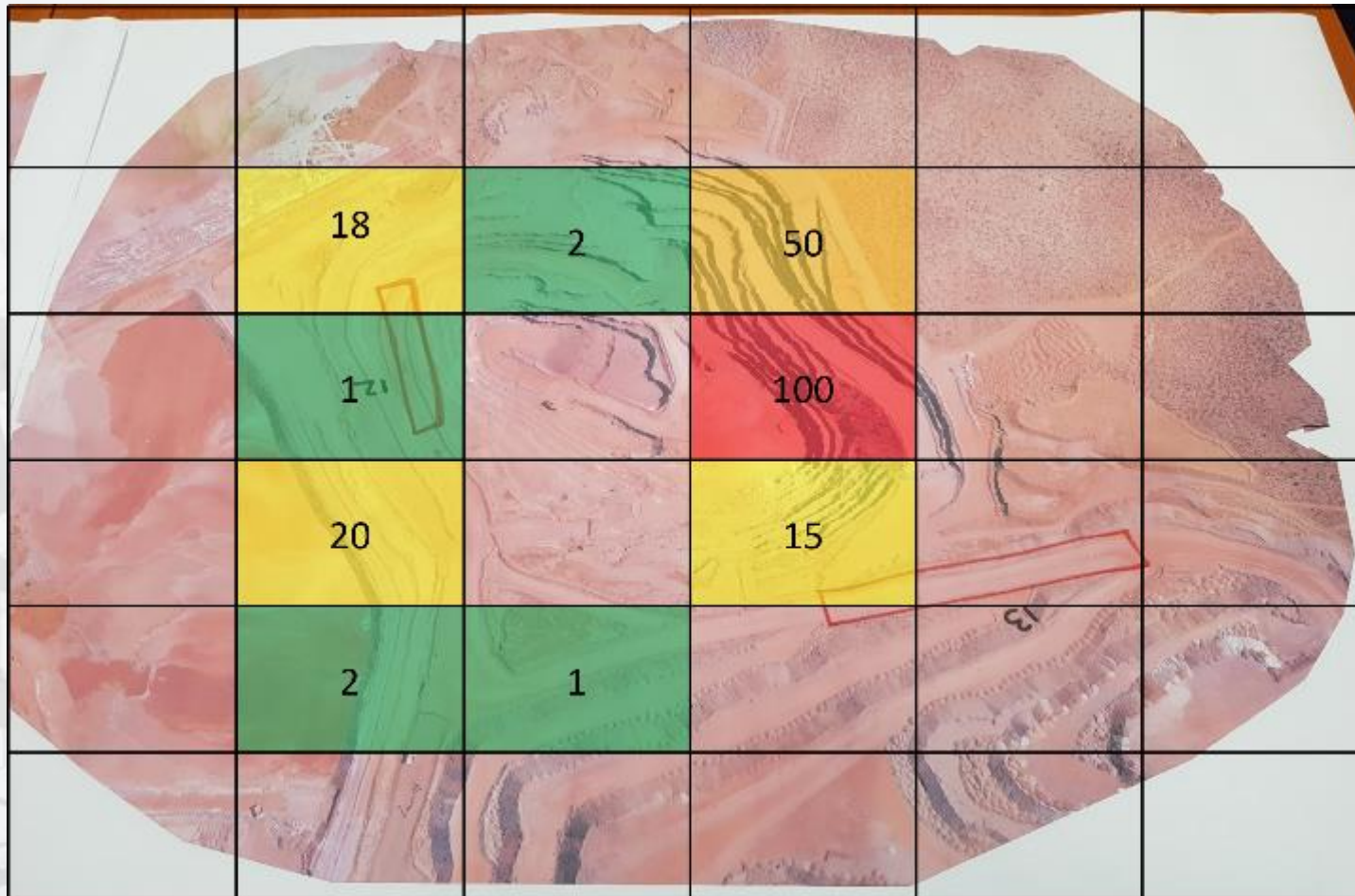


# CSIR Operational Pilot: Vehicle Interaction Analysis - Heatmap



**Important note:** Actual operational data is not shared due to data privacy

# CSIR Operational Pilot: Vehicle Interaction Events



| Interaction count |        |
|-------------------|--------|
| Very High         | Red    |
| High              | Orange |
| Medium            | Yellow |
| Low               | Green  |

## Statistics displayed

- Number of interaction events in each sector
- Colour grade based on count

# CSIR Operational Pilot: Measuring significant risk

## Qualitative Analysis

Likelihood of Occurrence (Probability of Occurrence)

|   | Impact / Severity |   |  |
|---|-------------------|---|--|
| 3 | 4                 | 5 |  |
| 2 | 3                 | 4 |  |
| 1 | 2                 | 3 |  |

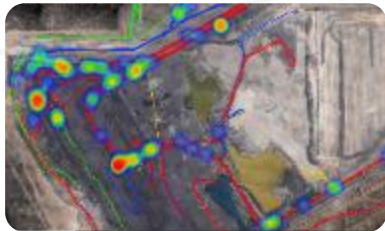
Risk Assessment Table

Update Likelihood of Occurrence

## Quantitative Analysis

TMM Digital Twin Simulation Frameworks

Simulation of key events to determine the **likelihood of occurrence**



Traffic Management Plan (TMP) Update

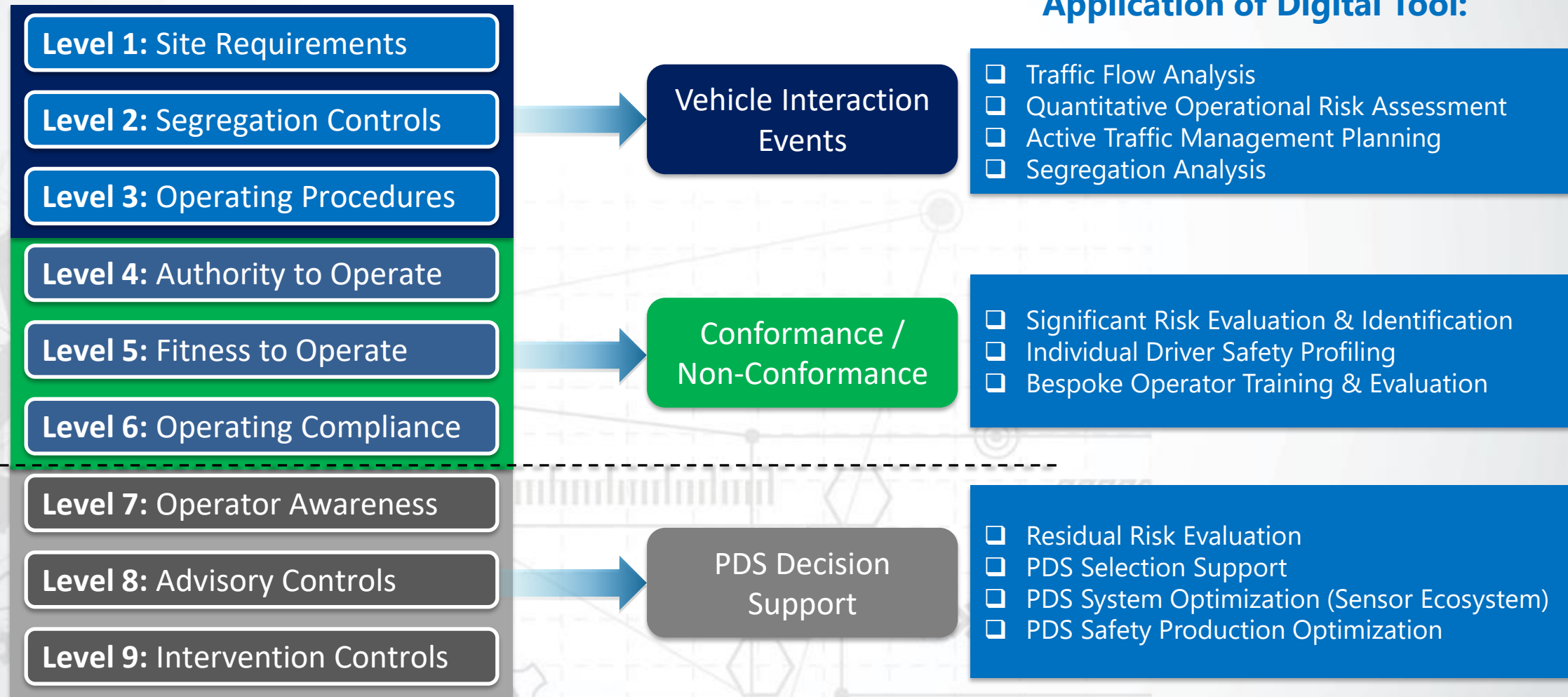


Update **TMP** by means of the TMM Digital Twin Cloud Based Interface



**Real-World Data:**  
Vehicle Logs  
TMP Event Capture

# CSIR Operational Pilot: Applications & future developments



Development: Fuel consumption analysis and decarbonization technology decision support

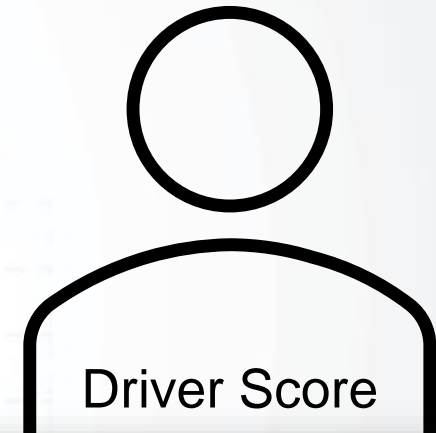
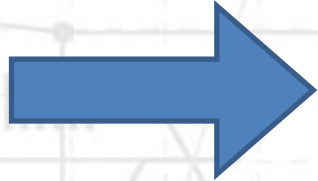
# CSIR Operational Pilot: Driver behaviour analysis



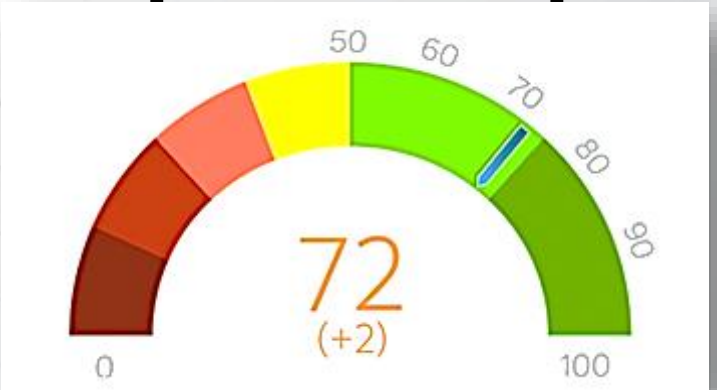
**Site Performance**

**Operator Profile**

- Work schedule
- Operator experience
- Class of vehicle



**Driver Score**



Accumulative score based on operator profile and site performance

# CSIR TMM Digital Twin: High-Level Timelines for a new Operational Site

| Work packages                                     | Activities   | Duration     | Requirements to ensure Rapid Deployment  |
|---|--|--------------|--|
| Operation understanding and requirements analysis | Stakeholder engagements, site visits, operation understanding, user requirements, etc.                         | 1 Month      | <ul style="list-style-type: none"> <li>• Involvement of discipline specific stakeholders</li> <li>• Availability of stakeholders</li> <li>• Well planned site visits</li> <li>• Well defined requirements (e.g., Reporting, Use Cases, Desired Information, etc.)</li> </ul>   |
| Data processing and management                    | Data acquisition, data analysis, data validation, procedures, etc.   | 1 Month      | <ul style="list-style-type: none"> <li>• Availability of client's data acquisition processes and methods</li> <li>• Data stored (ideal at least 6 months) and accessible (e.g., through API from a central database) to expedite data acquisition</li> <li>• Availability of Information Management or Data Management staff (assist with data related queries and processes)</li> </ul> |
| System configuration                              | Non-conformance analysis, vehicle interaction analysis, etc. based on the data received and user requirements. | 1 – 2 Months | <ul style="list-style-type: none"> <li>• Stakeholder engagements for analysis configuration, exclusions and pragmatic assumptions</li> </ul>   |

## Notes:

- ❑ These are indicative work packages and timelines
- ❑ Some of the activities can occur in parallel to expedite the implementation; e.g., data acquisition and site visits.
- ❑ The duration of the project is based on client's preference or requirements to have the Digital Twin service after the system is configured.



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