TMM REGULATORY ALIGNMENT PROJECT: TMM REGULATIONS

MINERALS COUNCIL SOUTH AFRICA

PURPOSE OF THE PROJECT:

To ensure **ALL** mines, TMM OEMs & CxD technology providers are ready for the **uplifting** of the **suspended clauses** of the TMM regulations by the **END of 2023.**

PURPOSE OF THE TMM REGULATIONS:

1. To **prevent TMM collisions** for surface TMMs.

CAUTION:
TMM approaching!
Apply brakes **NOW!**

STOP

2. To **prevent TMM & pedestrian collisions** for underground TMMs.

CAUTION:
Pedestrians ahead!
Apply brakes **NOW!**

STOP

! PREVENT ALL INJURIES NOT ONLY FATALITIES!

NO COLLISIONS = NO INJURIES

The **MAIN AIM** of the **TMM REGULATORY ALIGNMENT PROJECT** is to assist Mines to **COMPLY** with the regulations with the **LEAST EFFORT** and **OPPERATIONAL DISRUPTION.**
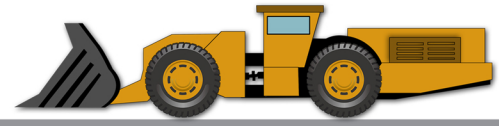
TMM FATALITIES 2015 - 2021:

Amount of fatalities recorded

Year	Value
2015	11
2016	8
2017	10
2018	10
2019	9
2020	3
2021	8

Period fatalities were recorded

DEFINITIONS:

- **CMS SOLUTIONS =** The **technology** or **combination** of **technologies** providing **proximity awareness**, operator **advisory** and/or collision **avoidance functionality**.

- **CPS = Collision Prevention System:** The **product system** that **complies** with the **RSA TMM regulatory** (Clauses 8.10.1 and 8.10.2) and **user requirements.**

- **CONTROL=** A **barrier** to **prevent against, or mitigate** the **consequences** of an **unwanted** event.

- **CPS LIFE CYCLE =** The **stages of a CPS product** from **inception** to **operation, maintenance, support and phase-out.**

- **CPS ECOSYSTEM =** All the **elements required** for **fully operational** CPS products in the South African **Mining Industry** including **human resource skills development.**

- **CxD = Collision Warning** and **Avoidance Device.**

- **DETECTION ZONE =** The **area around** a **TMM** where all **other TMMs** (surface) or **Pedestrians** (underground) are **detected** and wherein their **movements are tracked.**

- **VICINITY =** The **boundary** around a **TMM** where an **Effective Warning** must be given to the **TMM operators (Surface)** and the **TMM operator** and the **Pedestrian(s) (Underground).**

- **AUTO STOP ZONE =** The **boundary** around a **TMM** where an **auto-slow and stop intervention** is triggered.

- **EFFECTIVE WARNING = EW = Timeous** and sufficient **information** provided to the **TMM operators (Surface)** and the **TMM operator** and the **Pedestrian(s) (Underground)** to enable **prevention** of a potential **collision.**

- **SAFE SPEED =** The **speed** that will ensure the **controlled stopping** of a TMM **without** any **immediate negative impact** on the operator or the TMM itself.

- **FTS = Fail to Safe:** The **functionality** to bring a **TMM** to a **safe stop,** when **any CPS function fails.**

- **LEGACY EQUIPMENT = TMMs** that **do not have** the **required functionality** to **enable** a **CxD** to **fully function** correctly **without** being **upgraded.**

AFTER THE REGULATIONS ARE IN FORCE:

The TMM regulations do not allow for warning systems only(EMESRT L7).
- If LDVs are fitted with L7 before regulations are enforced, all **LDVs must** be **upgraded** to **CPS** or be **separated** from HMEs.

FREQUENTLY ASKED QUESTIONS:

Will CPS influence production negatively?
- After the initial phase, CPS should **not** have a negative impact on production.
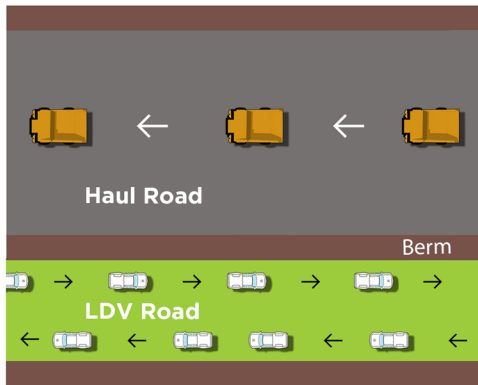
Will CPS influence TMM brake wear?
- **No,** if the CPS is working correctly there should be minimal auto slow and stop interventions. Operators must take action on Effective Warning.
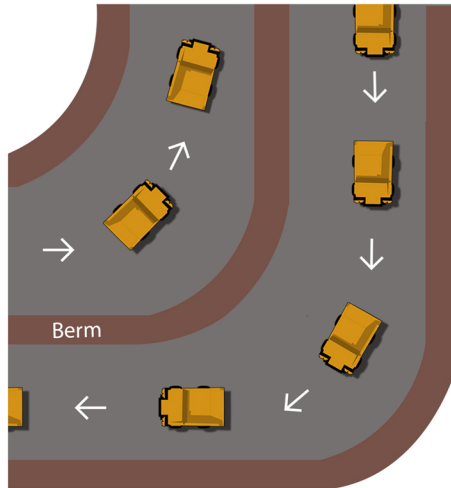
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? **WHAT ARE** SOME OF THE **OTHER CONTROLS** THAT CAN BE USED TO **PREVENT COLLISIONS** FOR **SURFACE TMMs?**

CONTROLS

Haul Road

Berm

LDV Road

Berm

Berm

Separate all **LDVs** from **HMEs.**

Separate HMEs on **Haul** roads.

STOP · STOP · Haul Road · Berm · STOP · STOP · Haul Road

STOP · STOP · Haul Road · Berm · STOP · STOP · Haul Road
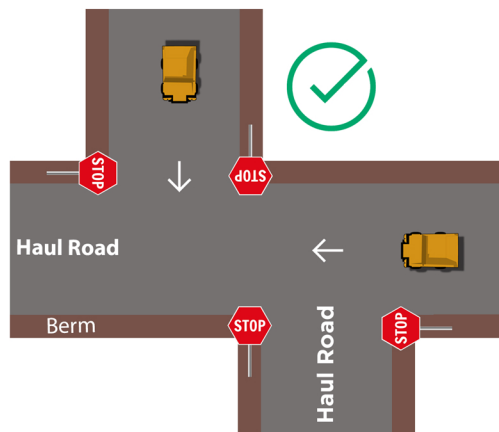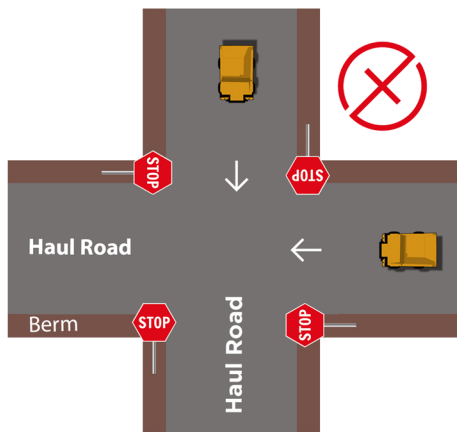
Eliminate **Crossover Intersections.**

Priority Road

Berm · STOP

Slowdown & stop **bumps/ditches.**
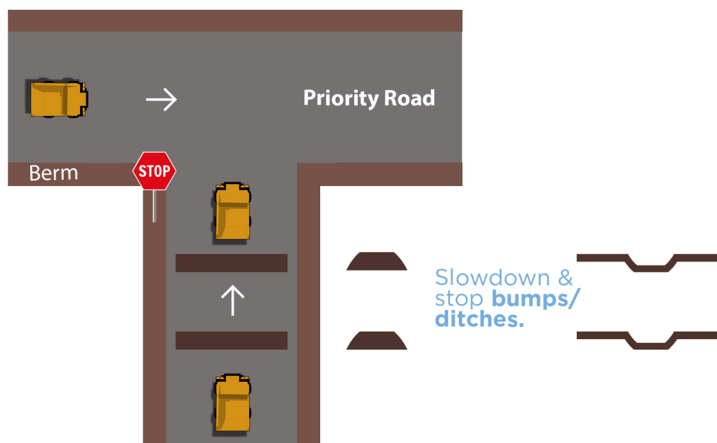
Introduce **slowdown & stop humps/ditches** at **Stops.**

WHAT QUALIFY AS CONTROLS?

✓ A **human act.** e.g. An **operator ensuring** his/her **TMM** is **fully operational before using it.** (Pre use inspection.)

✓ An engineered **object.** e.g. A **berm.**

✓ An engineered **system.** e.g. An **operator** stopping a **TMM** at a **stop-line.**

WHAT DO NOT QUALIFY AS CONTROLS?

⊗ Code Of Practice.

⊗ Procedure.

⊗ Training.

TMM
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PROJECT: OPERATIONAL READINESS

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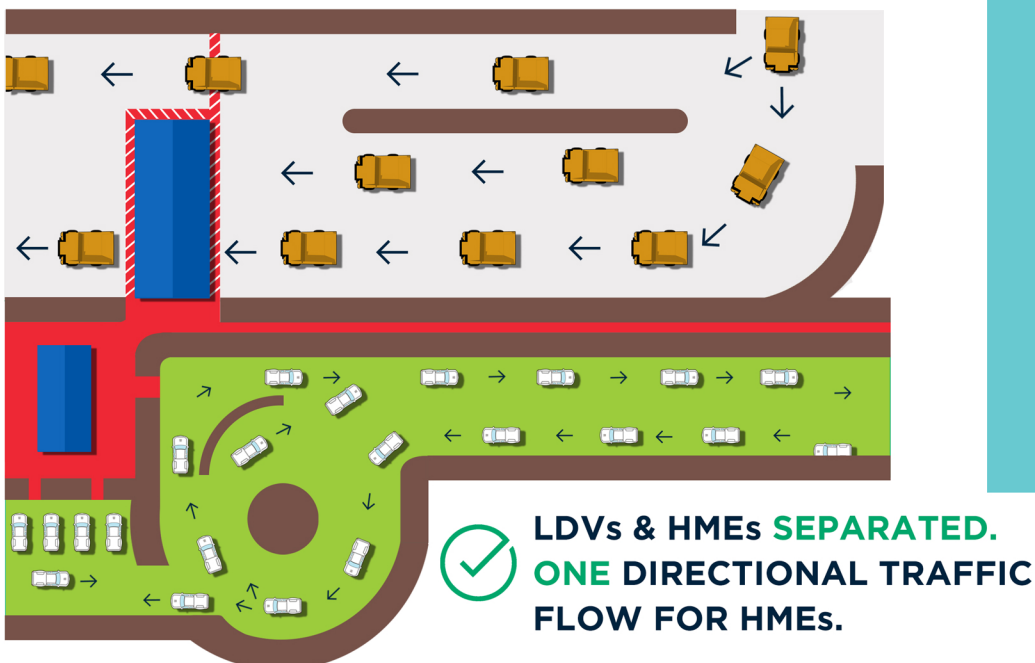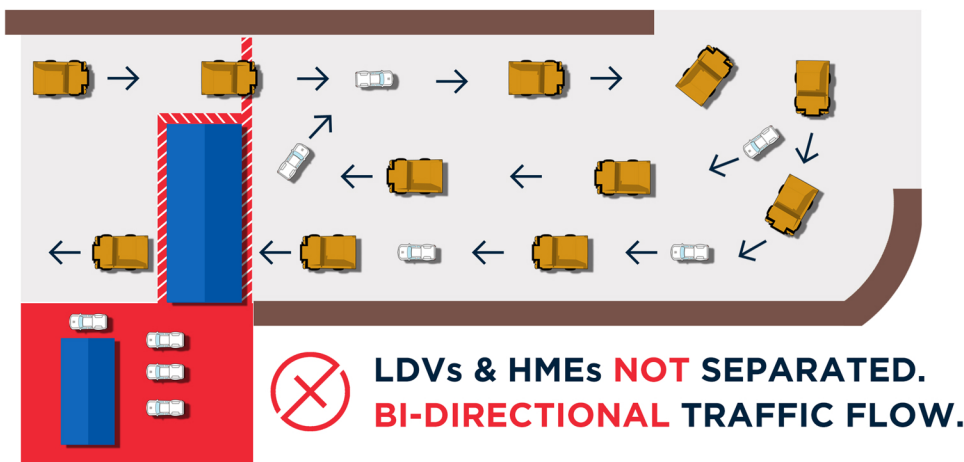**?** **WHAT ARE** SOME OF THE **OTHER CONTROLS** THAT CAN BE USED TO **PREVENT COLLISIONS** FOR **SURFACE TMMs?**

1. **SEPARATE LDVs** FROM **HMEs** IN WORKSHOP AREAS.

2. USE **ONE DIRECTIONAL FLOW** FOR HMEs.

⊗ LDVs & HMEs NOT SEPARATED. BI-DIRECTIONAL TRAFFIC FLOW.

✓ LDVs & HMEs SEPARATED. ONE DIRECTIONAL TRAFFIC FLOW FOR HMEs.
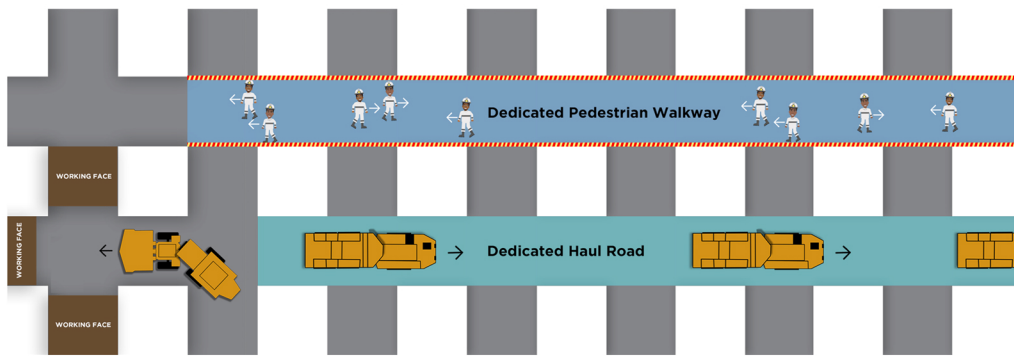
The **MOSH Surface Traffic Mangaement Leading Practice** provides a number of **elements** that include **controls** for **prevention** of TMM **collisions.** Including, but not limited to:

- **Traffic Flow & Risk Analysis.**

- **TMM Separation. Road Design &**

- **Construction.**

- **Zoning.**

- **Road Rules.**

- **Refuelling.**

- **Loading.**
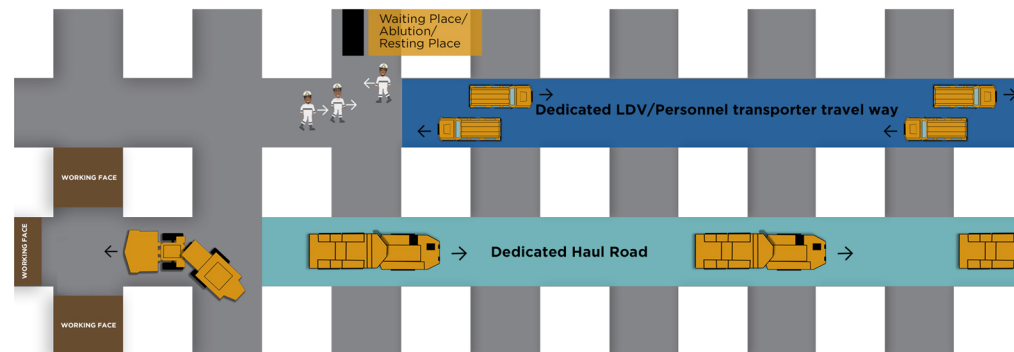
- **Dumping.**

- **Brake testing.**

CONTROLS

? **WHAT ARE** SOME OF THE **OTHER CONTROLS** THAT CAN BE USED TO **PREVENT COLLISIONS** FOR **UNDERGROUND TMMs?**

1. **Separate** pedestrians and TMMs by **dedicated** and **barricaded** pedestrian **walkways.**

Dedicated Pedestrian Walkway

WORKING FACE
WORKING FACE
WORKING FACE

Dedicated Haul Road

2. **Separate** pedestrians and TMMs by **providing dedicated transportation** for pedestrians.

Waiting Place/
Ablution/
Resting Place

Dedicated LDV/Personnel transporter travel way

WORKING FACE
WORKING FACE
WORKING FACE

Dedicated Haul Road

3. **Separate** pedestrians and TMMs by **dedicated time slots.**
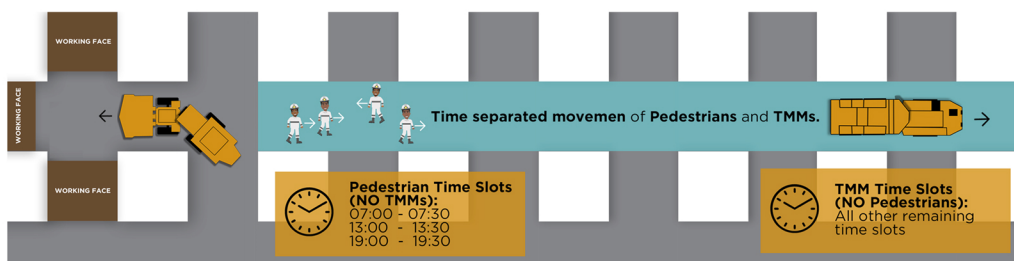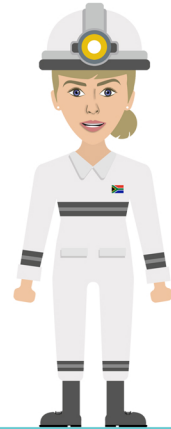
WORKING FACE
WORKING FACE
WORKING FACE

Time separated movemen of Pedestrians and TMMs.

Pedestrian Time Slots (NO TMMs):
07:00 - 07:30
13:00 - 13:30
19:00 - 19:30

TMM Time Slots (NO Pedestrians):
All other remaining time slots

WHAT QUALIFY **AS CONTROLS?**

✓ A **human act.** e.g. An **operator ensuring** his/her **TMM** is **fully operational before using it.** (Pre use inspection.)

✓ An engineered **object.** e.g. A **berm.**

✓ An engineered **system.** e.g. An **operator** stopping a **TMM** at a **stop-line.**

WHAT DO NOT QUALIFY **AS CONTROLS?**

✗ Code Of Practice.

✗ Procedure.

✗ Training.

The **MOSH Underground Traffic Management Guideline** provides **guidance** for the **safe movement** of **TMMs** and **pedestrians** in **Underground** Operations.

TMM
REGULATORY
ALIGNMENT
PROJECT: OPERATIONAL READINESS

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? **WHAT ARE** SOME OF THE **OTHER CONTROLS** THAT CAN BE USED TO **PREVENT COLLISIONS** FOR **UNDERGROUND TMMs?**
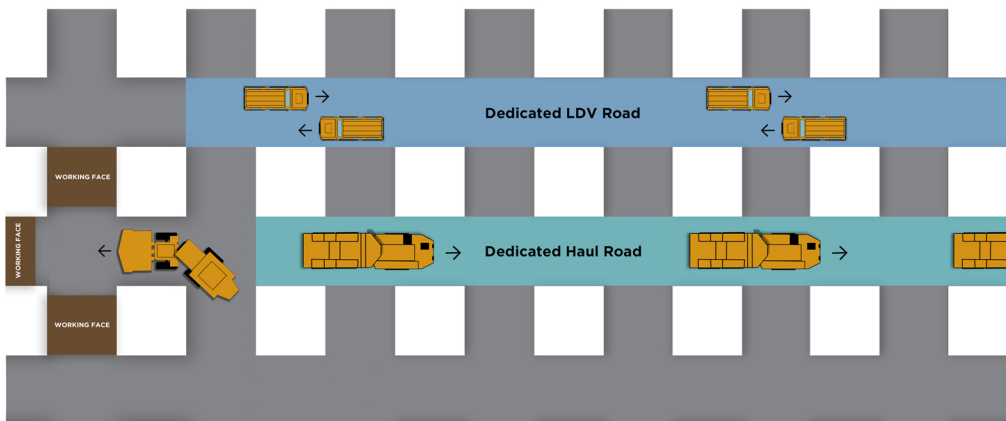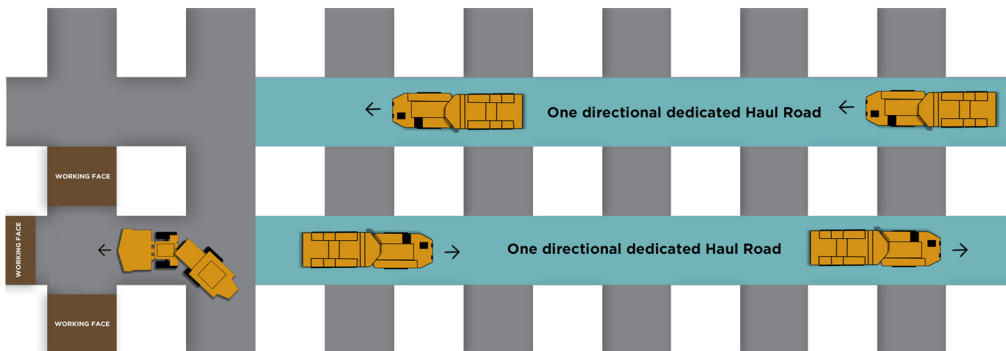
4. Separate LDVs and HMEs by dedicated roads.

WORKING FACE

WORKING FACE

Dedicated LDV Road

Dedicated Haul Road

WORKING FACE

5. Separate HMEs by one directional flow .

WORKING FACE

WORKING FACE

One directional dedicated Haul Road

One directional dedicated Haul Road

WORKING FACE

6. Separate the mine TMMs by developing three dedicated travel ways.

WORKING FACE

WORKING FACE

WORKING FACE

Dedicated LDV/Personnel transporter travel way

One directional dedicated Haul Road

One directional dedicated Haul Road
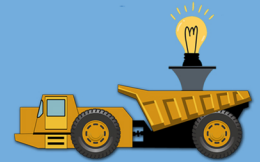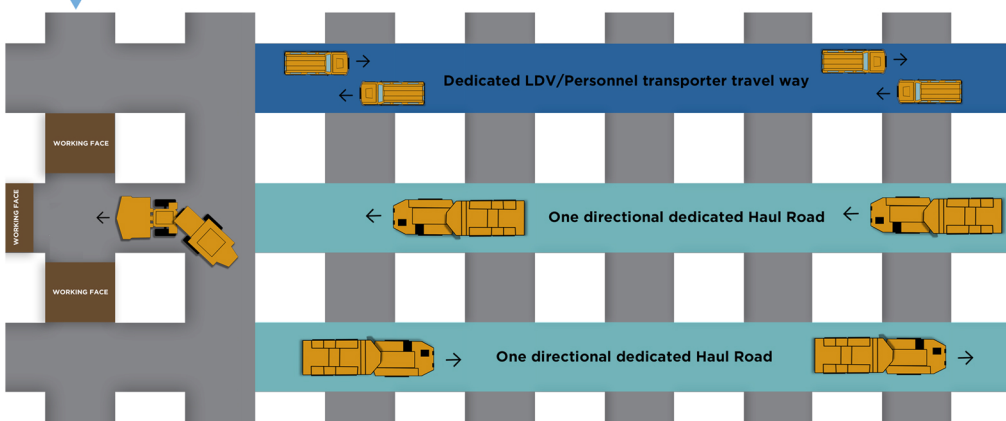
UNDERGROUND TRAFFIC MANAGEMENT PRINCIPLES / RULES:

- **Intersections** to be regulated by **boom-gates** or **beacon-control.**

- All **TMM parking areas** to be clearly **demarcated** and **parking rules** to be **sign- posted** at parking areas.

- **Pedestrians** to walk on **dedicated demarcated** walkways **only.**

- All **contractor movement** to **follow** the mine's **traffic management** principles and rules.

- **Road development** to follow **ventilation principles.**

REGULATORY IMPLICATIONS: [OUR CHALLENGE]

- **All mines,** where there is a **significant risk** of TMM collision, must be CPS enabled by **a specific date.**
- **Legacy** TMMs require **upgrades.**
- **Limited time** for product **introduction to mines.**
- **Specific functions** are required.
- **Ground breaking application** of the CPS technology.
- Requires **establishment** of the **entire CPS ecosystem.**

THE CPS TECHNOLOGY READINESS APPROACH:
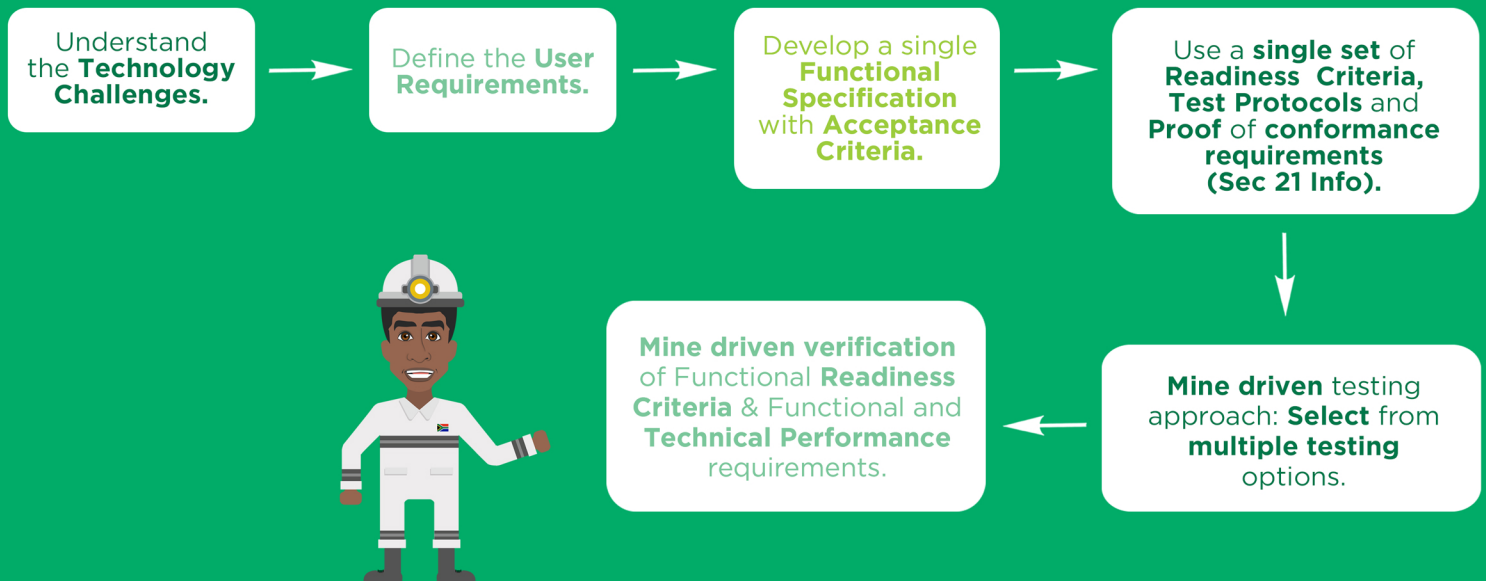
Understand the **Technology Challenges.** → Define the **User Requirements.** → Develop a single **Functional Specification** with **Acceptance Criteria.** → Use a **single set** of **Readiness Criteria, Test Protocols** and **Proof** of **conformance requirements (Sec 21 Info).**

Mine driven verification of Functional **Readiness Criteria** & Functional and **Technical Performance** requirements. ← **Mine driven** testing approach: **Select** from **multiple testing** options.

KEY PRINCIPLES OF THE CPS TECHNOLOGY READINESS APPROACH:

1. Centralised Requirements Facilitation.
2. **Systems Engineering Approach.**
3. Extensive Collaboration.
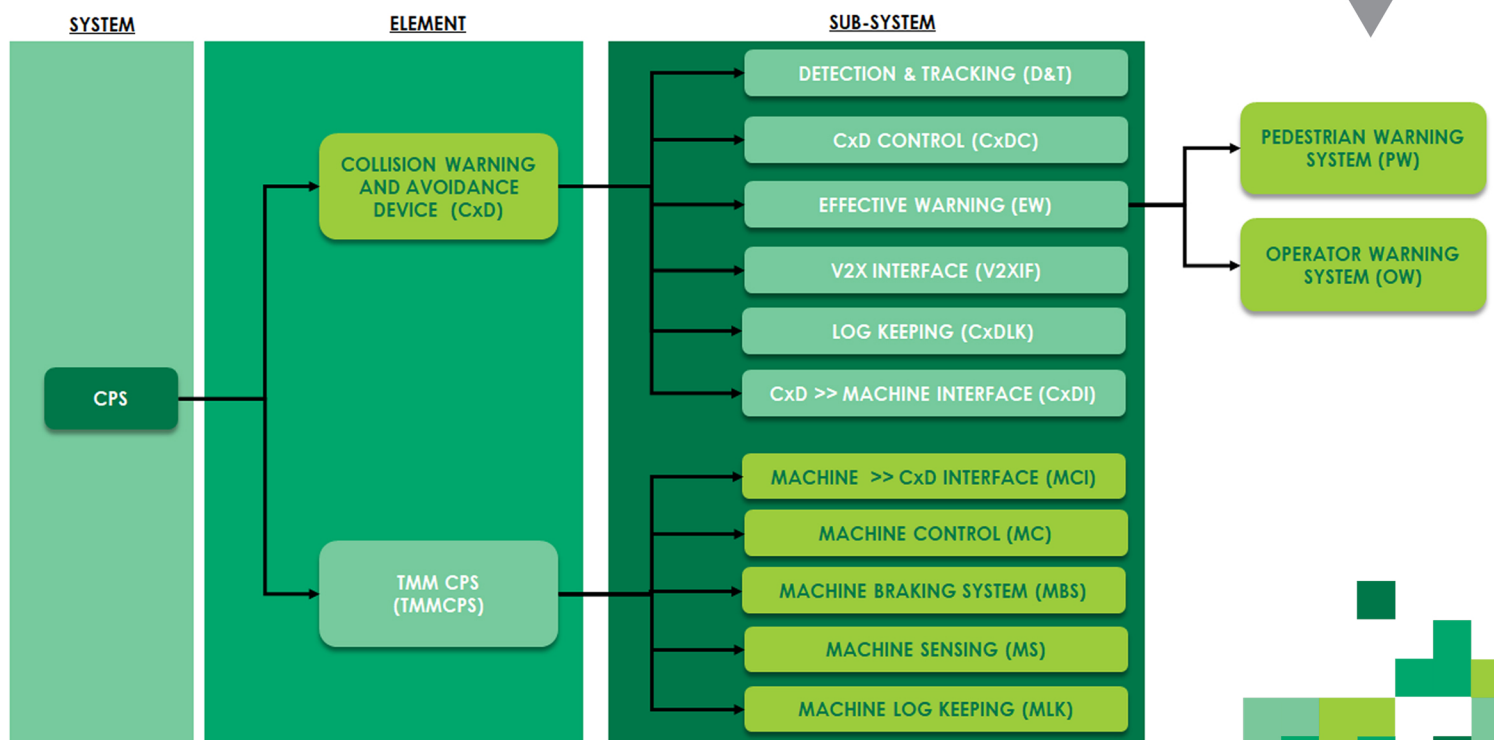4. **Independent Verification & Testing.**

TMM REGULATORY ALIGNMENT PROJECT: CPS BREAKDOWN STRUCTURE

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ACRONYMS:

- **CxD =** Collision Warning and Avoidance Device.
- **CxDC =** CxD Control.
- **CxDI =** CxD Machine Interface.
- **CxDLK =** CxD Log Keeping.
- **D&T =** Detection and Tracking.
- **EWS =** Effective Warning.
- **MCI =** Machine CxD interface.
- **MC =** Machine Controller.
- **MBS =** Machine Braking System.
- **MS =** Machine Sensing.

- **MLK =** Machine Log Keeping.
- **OWS =** Operator Warning System.
- **PDS =** Proximity Detection System
  Note: PDS is a colloquial industry term for a physical device providing a **warning or collision avoidance functionality.**
- **PWS =** Pedestrian Warning System.
- **TMM CPS =** Trackless Mobile Machinery Collision Prevention System.
- **V2X =** Vehicle to anything.
- **V2XI =** V2X Interface.

SYSTEM	ELEMENT	SUB-SYSTEM	
		DETECTION & TRACKING (D&T)	
	COLLISION WARNING AND AVOIDANCE DEVICE (CxD)	CxD CONTROL (CxDC)	PEDESTRIAN WARNING SYSTEM (PW)
		EFFECTIVE WARNING (EW)	OPERATOR WARNING SYSTEM (OW)
CPS		V2X INTERFACE (V2XIF)	
		LOG KEEPING (CxDLK)	
		CxD >> MACHINE INTERFACE (CxDI)	
	TMM CPS (TMMCPS)	MACHINE >> CxD INTERFACE (MCI)	
		MACHINE CONTROL (MC)	
		MACHINE BRAKING SYSTEM (MBS)	
		MACHINE SENSING (MS)	
		MACHINE LOG KEEPING (MLK)	

CPS **FUNCTIONAL BREAKDOWN** STRUCTURE:

- **One** System → **CPS.**
- **Two** Elements → **TMM CPS** and **CxD.**
- **One** Interface Standard → **ISO21815-2 2021.**
- Synchronised Log Keeping on both **CxD** and **TMM CPS.**
- Currently no International **V2X** communication Standard.
- **Legacy TMMs** may need additional sensing and Machine Braking System functions.
- **Effective Warning** for Operators and Pedestrians.
- **CxD** and **TMM CPS** Controllers to be **Synchronised.**

TMM REGULATORY ALIGNMENT PROJECT: CPS FUNCTIONS

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SURFACE TMMs: WHAT DO THE REGULATIONS REQUIRE?

1. TMMs must **detect EACH OTHER.**

Potential **"Collision Point"**

TMM D **'Detection Zone'**

TMM C **'Detection Zone'**

TMM B **'Detection Zone'**

TMM A **'Detection Zone'**
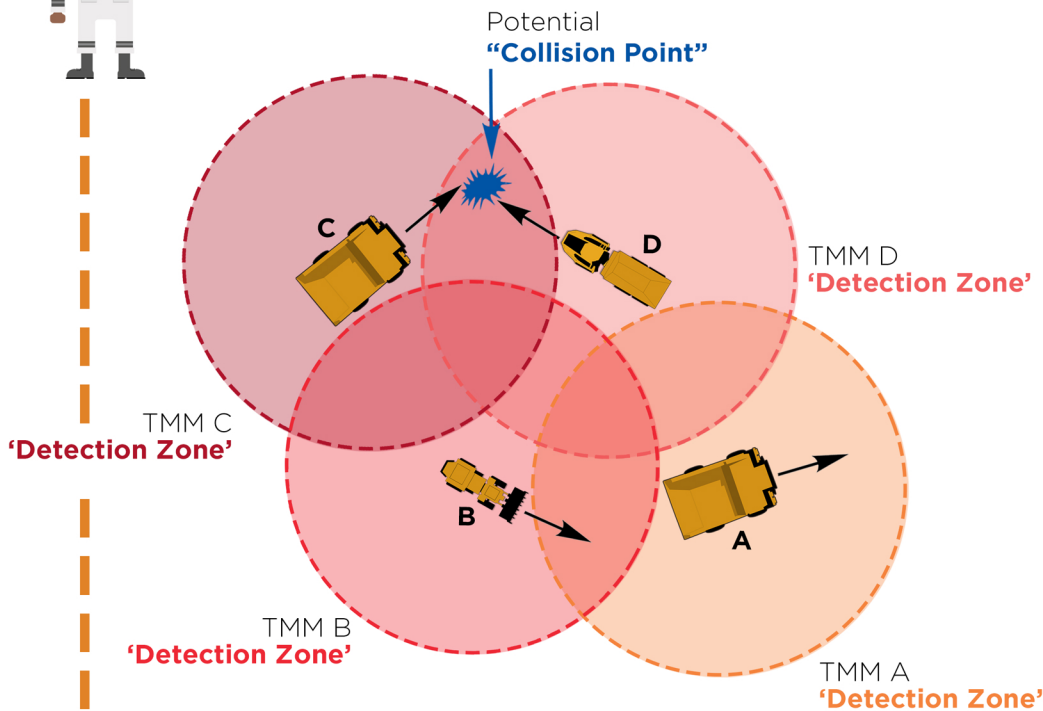
2. When in the vicinity of each other **BOTH** operators must be given an **EFFECTIVE** warning.

TMM A **'Vicinity'**

Vicinity Boundary

TMM B **'Vicinity'**

CAUTION: TMM ahead! Apply brakes **NOW!**
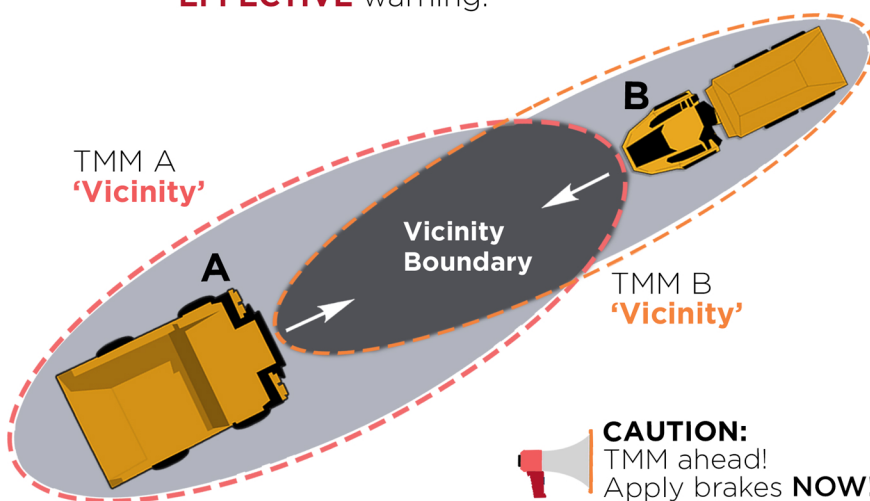
BOTH operators **MUST** take appropriate action!

NO priority TMMs!

APPROPRIATE action must **PREVENT** a potential collision!

DETAILED FUNCTIONS OF DETECTION:

- **All** TMMs in the **'Detection Zone'** must be able to detect **each other.**

- **Each** TMM must **detect all TMMs** inside the **'Detection Zone'** only **once,** even though all TMMs **might be moving.**

- **Each** TMM must track the **movement** of **all other TMMs** in the **'Detection Zone'.**

- **Each** TMM must **determine the risk** of a **potential collision** with all **other TMMs** inside the **'Detection Zone'.**

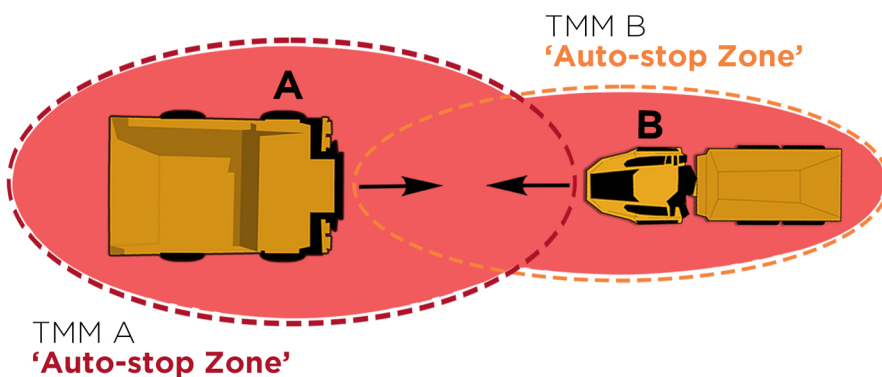## DETAILED FUNCTIONS OF EFFECTIVE WARNING:

- Warn **only** at **vicinity boundary.**

- **Vicinity** must allow **operators of both TMMs** to take action i.e. vicinity to be dynamic, depending on: direction, speed, braking characteristics etc.

- **Effective warning** to provide **clear instructions** to **both** TMM operators.

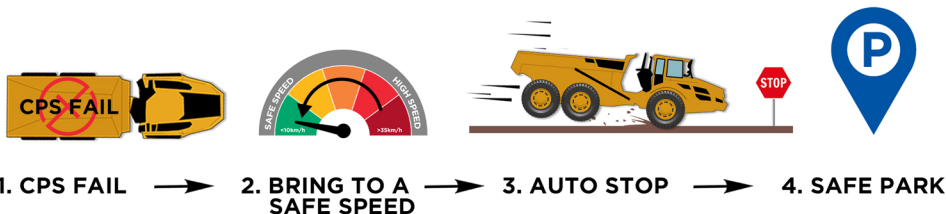- **Both operators** are allowed **2,5 sec** to take **action.**

TMM REGULATORY ALIGNMENT PROJECT: CPS FUNCTIONS

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SURFACE TMMs: WHAT DO THE REGULATIONS REQUIRE?

3. **BOTH TMMs** must be able to **AUTOMATICALLY** stop **SAFELY.**

TMM B
'Auto-stop Zone'

A

B

TMM A
'Auto-stop Zone'

4. The **CPS** must **FAIL** to **SAFE** without **HUMAN INTERVENTION.**

CPS FAIL

SAFE SPEED   HIGH SPEED
<10km/h   >35km/h

STOP

P

1. CPS FAIL ➜ 2. BRING TO A SAFE SPEED ➜ 3. AUTO STOP ➜ 4. SAFE PARK

DETAILED FUNCTIONS OF AUTO-STOP:

● **Stopping** without operator **intervention.**

● **Stopping** without any **adverse effect** on the **operators.**

● Auto-stopping of **both TMMs.** (No priority TMMs.)

● Slow down to a **safe speed before stopping.** (If required.)

● Predetermined **deceleration rates.**

DETAILED FAIL TO SAFE FUNCTIONS:

● If any of the **CPS elements fail** the **TMM must be** brought to a **safe speed,** the **TMM** must **automatically** be **stopped** and put into **safe park.**

KEY FUNCTIONS OF THE CPS:

- Detect **early** but **don't warn.**
- **Track** all detected **TMMs** while they **move inside** the **Detection Zone.**
- **Determine** the risk of **TMM collision** continuously: speed, direction, etc.
- When **TMMs** are in the **VICINITY,** then **only** warn **operators.**

BOTH TMMs **MUST** Auto-stop!!

NO priority TMMs!

TMM
REGULATORY
ALIGNMENT
PROJECT: CPS FUNCTIONS

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UNDERGROUND TMMs: WHAT DO THE REGULATIONS REQUIRE?

1. TMMs must **detect** PEDESTRIANS.

TMM A
'Detection Zone'
(30m radius)

TMM B
'Detection Zone'
(30m radius)

A

B

WORKING FACE

Potential
"Collision Point"

WORKING FACE

C

WORKING FACE

TMM C
'Detection Zone'
(30m radius)
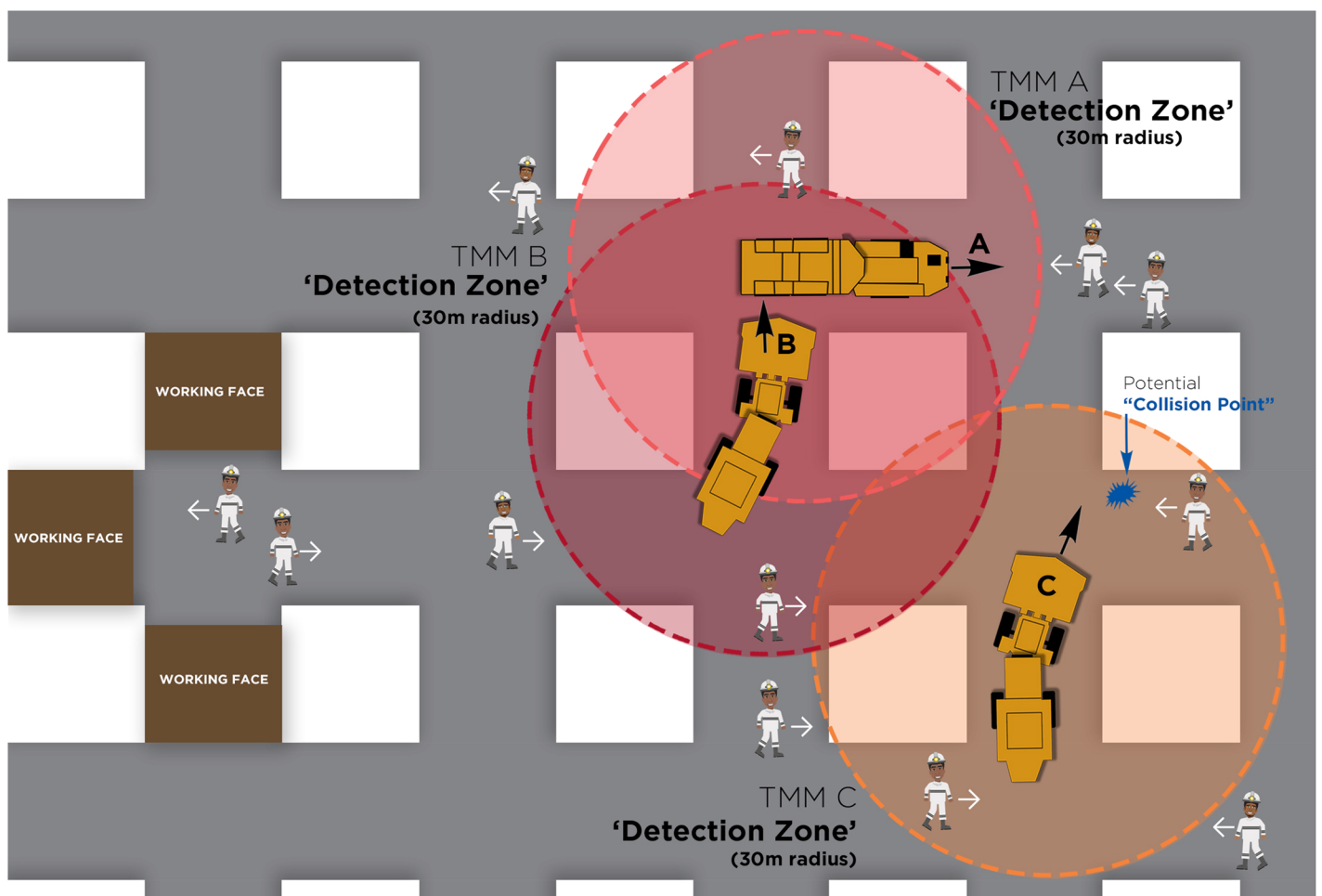
DETAILED FUNCTIONS OF D E T E C T I O N :

- **All** TMMs in the **'Detection Zone'** must be able to detect **all pedestrians** in the **'Detection Zone'**.

- **Each** TMM must **detect** every **pedestrian only once,** despite **continuous movement** of the pedestrians.

- **Each** TMM must **track** the movement of **all pedestrians** in the **'Detection Zone'**.

- **Determine** the risk of **a potential collision** between the **TMM** and all the **pedestrians** in the **'Detection Zone'**.
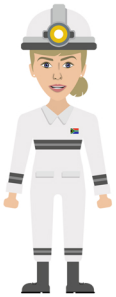
UNDERGROUND TMMs: WHAT DO THE REGULATIONS REQUIRE?

2. When in the vicinity of each other, **BOTH** the operator and the pedestrian must be given an **EFFECTIVE** warning.

CAUTION: Pedestrian ahead!

TMM A **'Pedestrian Warning Zone'**

A→ 5m

Pedestrian Warning:
- beep - beeep - beeep
- Yellow flashing light
TMM:
- Warning only

B

TMM B **'Auto Slow-Down Zone'**

WORKING FACE

WORKING FACE

CAUTION: Pedestrian ahead! Slow down **NOW!**

4m

Pedestrian Warning:
- beep - beep - beep
- ORANGE flashing light
TMM:
- Slow-down

WORKING FACE

NOTE: Distances indicated are **indicative** only. **Values** to be determined by **every Mine** based on its **unique operations.**

TMM C **'Auto-Stop Zone'**

Pedestrian Warning:
- beeeeeeeeeeeeeep
- RED flashing light
TMM:
- Stop

C

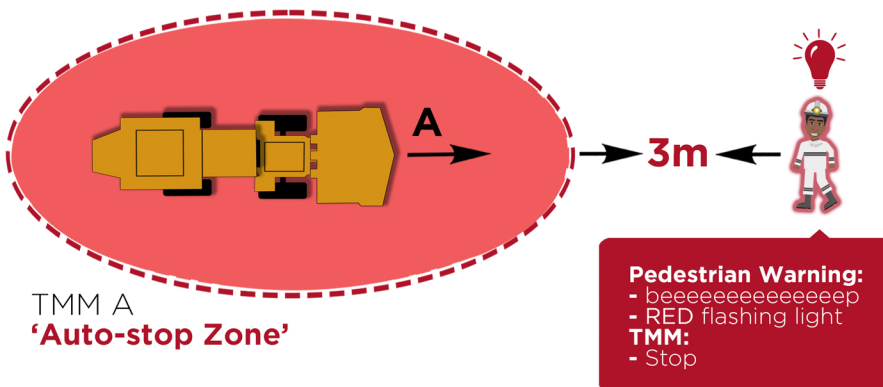**CAUTION:** Pedestrian ahead! Stop **NOW!**

3m

DETAILED FUNCTIONS OF EFFECTIVE WARNING:

- The **pedestrian** to be **warned** when **5m** away from the **TMM.**

- The **pedestrian** to be **warned** to **move away** when **4m** away from the **TMM.** The **TMM operator** to **slow down** the **TMM / auto-slow down.**

- The **pedestrian** to be **warned** to **move away** when **3m** away from the **TMM.** The **TMM operator** to **stop** the **TMM / auto-stop.**

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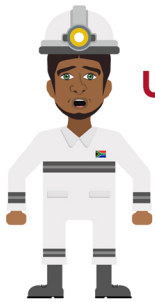
UNDERGROUND TMMs: WHAT DO THE REGULATIONS REQUIRE?

3. The **TMM** must be able to **AUTOMATICALLY** stop **SAFELY.**

A → 3m ←

TMM A
'Auto-stop Zone'

Pedestrian Warning:
- beeeeeeeeeeeeep
- RED flashing light
TMM:
- Stop

4. The **CPS** must **FAIL** to **SAFE** without **HUMAN INTERVENTION..**

CPS FAIL

1. CPS FAIL → 2. BRING TO A SAFE SPEED → 3. AUTO STOP → 4. SAFE PARK

DETAILED FUNCTIONS OF A U T O - S T O P :

- **Stopping** without operator **intervention.**

- **Stopping** without any **adverse effect** on the **operators.**

- Auto-stopping of **TMM.** (No priority TMMs.)

- Slow down to a **safe speed before stopping.** (If required.)

- Predetermined **deceleration rates.**

DETAILED FAIL TO SAFE FUNCTIONS:

- If any of the **CPS elements fail** the **TMM must be** brought to a **safe speed,** the **TMM** must **automatically** be **stopped** and put into **safe park.**
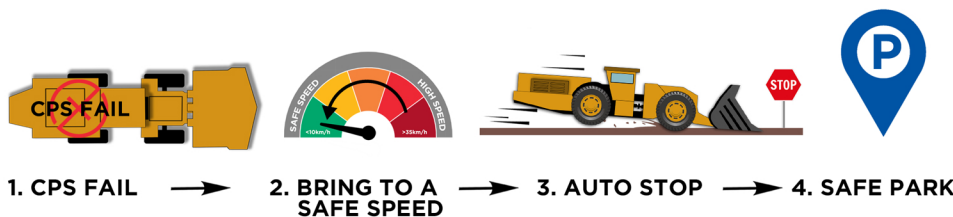
KEY FUNCTIONS OF THE CPS:

- Detect **early** but **don't warn.**
- **Track** all **detected pedestrians** while they **move.**
- **Determine** the risk of **pedestrian collision** continuously: speed, direction, etc.
- **Only** when **pedestrian(s)** are in the **VICINITY, warn** operator **and** pedestrian(s).
- If pedestrian(s) **don't** take action - auto-slow and **stop TMM.**

TMM REGULATORY ALIGNMENT PROJECT: CxD FUNCTIONAL ELEMENTS
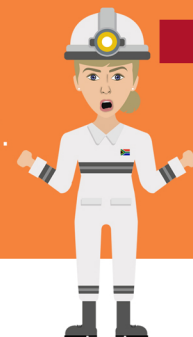
THE CxD:

The **CxD** is a **device** with **sensors,** providing **collision warning** and **prevention** functions. It **detects objects** in the **detection area/zone** of the TMM, **assesses** the level of **collision risk** and **effectively warns** the operator(s) and/or pedestrian(s). It then **provides signals** to the machine **controller** to initiate the **appropriate collision prevention action(s).**

THE TMM CPS:

The **TMM CPS provides** all the functionalities **required** by the **TMM** to ensure **conformance** to the **TMM CPS functional** and **user requirements.**
(It makes a TMM ready for CPS functions.)

! THE CxD FUNCTIONS ARE STRUCTURED INTO 6 SUB-GROUPS:

1. The **D&T function ensures detection** of all **TMMs (Surface TMMs)** or **Pedestrians (Underground TMMs)** within a **predefined area (detection area)** and the **tracking of the movement** of **each detected** TMM/pedestrian. Based on **specific aspects** of the **movement** such as **direction** and **speed, potential risk of collision** for **each TMM/Pedestrian** is determined. When a **detected TMM/Pedestrian** enters the **vicinity** of the **detecting TMM,** the **D&T provides** the **MCI** with an appropriate **signal.**

2. The **CxDC** provides the **control functions** and **signals to and from** other **CPS elements** and/or **sub systems** to ensure **correct functioning** of all the **CPS functions.**

3. The **EWS** comprises of **specific functions** for **Surface TMMs** and **other functions** for **Underground TMMs.** The **OWS** provides the **TMM operators** with an **effective warning** to **take action** to **prevent a potential collision.** The **PWS provides** the **pedestrian(s)** with an **effective warning** to take **action** to **prevent a potential collision.**

4. The **V2X interface** provides communication between **different CxD devices.** *Note:* **V2X** is a **catch-all term** for **vehicle-to-everything.** It may refer to **vehicle-to-vehicle** (V-V)**, vehicle-to-pedestrian** (V-P), or **vehicle-to-environment** (V-E). Due to **unavailability** of a **standardised** V2X interface for **CPS** the **South African Mining Industry** (SAMI) decided to use a **single CxD product** on every mine.

5. The **CxDLK** provides for all the **recording** and **log keeping functions** of all the **relevant data** and **instructions** sent from the **CxD** and **received** from the **MCI.**

6. The **CxDI** enables **communication** between the **CxD** and the **TMM CPS** as per the **ISO 21815-2 2021 standard.**
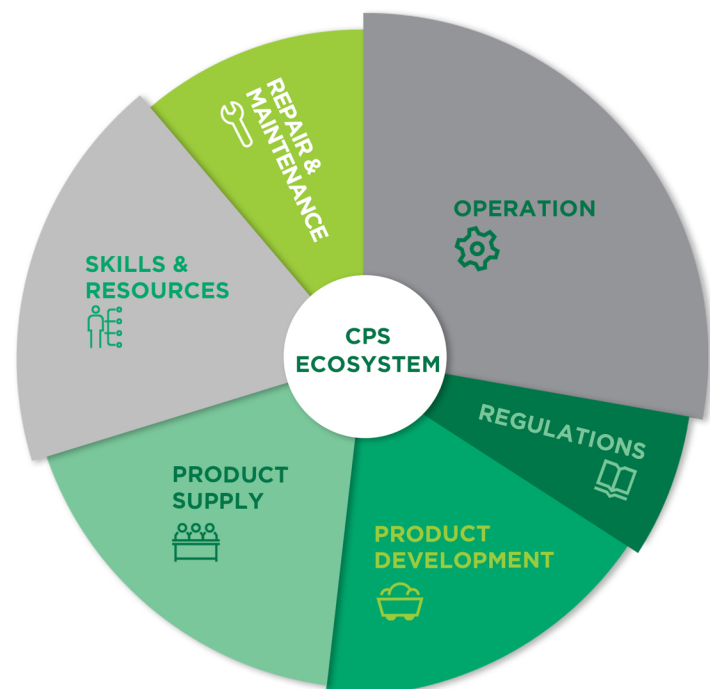
TMM
REGULATORY
ALIGNMENT
PROJECT: TMM CPS FUNCTIONAL ELEMENTS

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THE **TMM CPS FUNCTIONS** ARE STRUCTURED IN **5 SUB-GROUPS:**

1. The **MCI** enables **communication** between the **TMM CPS** and the **CxD** as per the **ISO 21815-2 2021 standard.**

2. The **MC** provides **specific functions** to **control** the **TMM** when **receiving** specific **instructions/ signals** from the **CxD.**

3. The **MBS** comprises of **all** the **hardware** and **software functions** to **enable auto slow-down** and **stop** functionality to the **TMM.**

4. The **MS** provides the **TMM** with the **functionality required** to **ensure** the **correct functioning** of the **CPS.** This might include sensing of loads, speeds, inclinations etc.

5. The **MLK** provides for **all the recording** and **log keeping** of all the **relevant data received** and **sent** to the **CxD** as well as the **instructions sent to** and **received from** the **TMM CPS subsystems** or components.
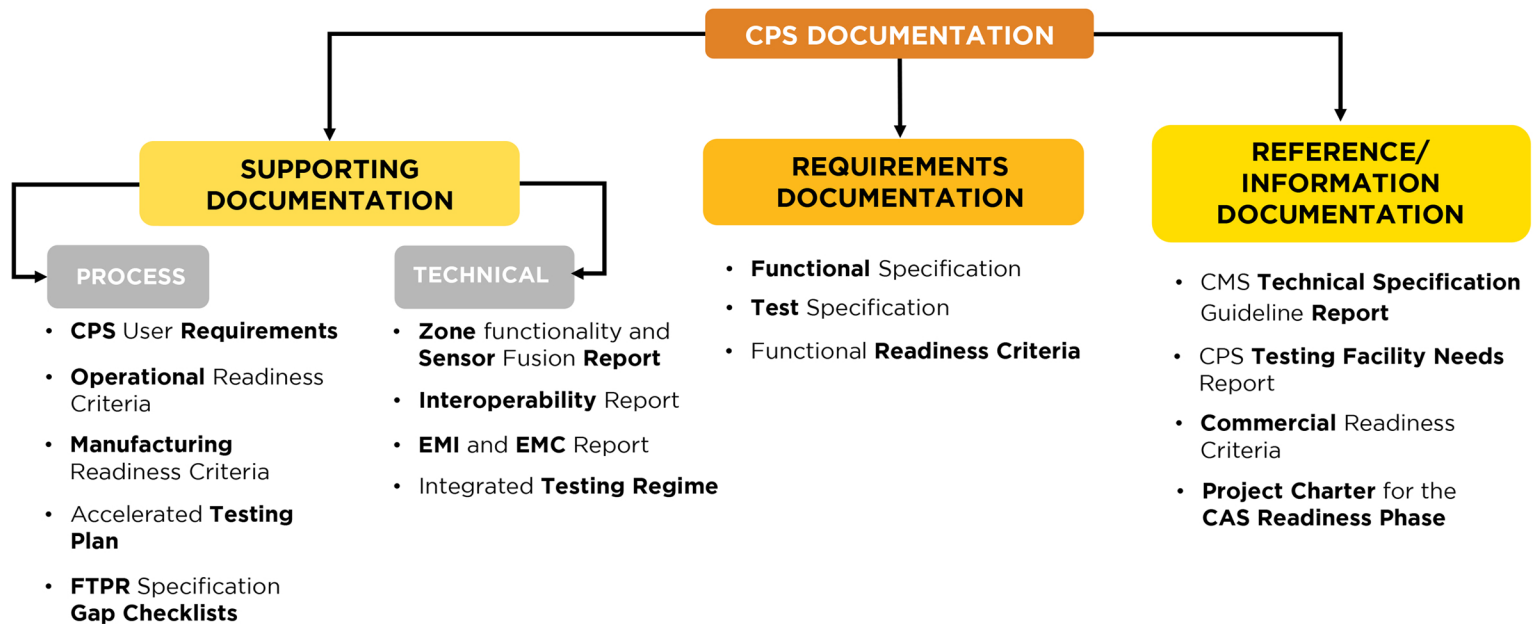
THE **CPS ECOSYSTEM:**

For the **SAMI** to be **ready** for the **lifting of suspended TMM Regulations,** an entire **Ecosystem** must be **established** in order to ensure **uninterrupted** production.

REPAIR & MAINTENANCE

OPERATION

SKILLS & RESOURCES

CPS ECOSYSTEM

REGULATIONS

PRODUCT SUPPLY

PRODUCT DEVELOPMENT

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The **TMM Regulatory Alignment Project** created a number of **Technical Documents** to **assist mines** with **CPS introduction.**

COLLISION PREVENTION SYSTEMS DOCUMENTATION TREE:

CPS DOCUMENTATION

SUPPORTING DOCUMENTATION

PROCESS

- **CPS** User **Requirements**
- **Operational** Readiness Criteria
- **Manufacturing** Readiness Criteria
- Accelerated **Testing Plan**
- **FTPR** Specification **Gap Checklists**

TECHNICAL

- **Zone** functionality and **Sensor** Fusion **Report**
- **Interoperability** Report
- **EMI** and **EMC** Report
- Integrated **Testing Regime**

REQUIREMENTS DOCUMENTATION

- **Functional** Specification
- **Test** Specification
- Functional **Readiness Criteria**

REFERENCE/ INFORMATION DOCUMENTATION

- CMS **Technical Specification** Guideline **Report**
- CPS **Testing Facility Needs** Report
- **Commercial** Readiness Criteria
- **Project Charter** for the **CAS Readiness Phase**

The **Full Suite** of **CPS Technical Documents** are on the MOSH website link **https://www.mosh. co.za/transport-and-machinery/documents.**

The **CPS Technical Requirement** and **Supporting Documents** are a **yardstick** for mines for **CPS ecosystem readiness.**

Updates to the **CPS Technical Documents** are continuously **updated and published in the CPS Documentation Change Register on the above** mentioned Mosh website.