READINESS CRITERIA FOR COLLISION PREVENTION SYSTEMS DEVELOPMENT

PART 3: OPERATIONAL READINESS

(I.E., WORK PACKAGE 8)

INDUSTRY ALIGNMENT ON TMM REGULATIONS; SPECIAL PROJECT OF THE MINERALS COUNCIL SOUTH AFRICA

REV 3

CPS Readiness Criteria Acceptance			
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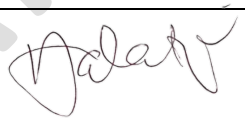
Stanford Malatji		**Minerals Council**	20 June 2022

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1. Purpose of this document

This document sets out the criteria for the operational readiness for mines to introduce CPS products.

2. Definitions and abbreviations

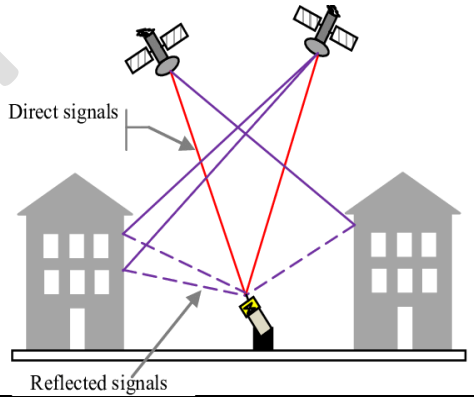
The following definitions and abbreviations will be used to create a common approach for all deliverables. (Note: The rationale for some of the terms and definitions is set out in the CMS Technical Specification Guideline Review Report).

3rd Party	An entity appointed to execute work (testing, witnessing of testing and verifying portfolios of evidence) on behalf of SAMI. Note: The purpose of 3rd party execution is to establish independence and to eliminate duplication.
Accelerated Development	Development of CPS products in a coordinated and integrated way that will require less time (for the entire SAMI need), than the previous individual mine and supplier / OEM driven CPS product development approach.
Accelerated Testing	An initiative to accelerate the testing of CPS solutions with reference to the original test approach and plan.
Accuracy	The degree to which the result of a measurement, calculation, or estimate conforms to the correct value, i.e. the preciseness of the measurement.
C102-F9R	C102-F9R application board Easy evaluation of ZED-F9R with sensor fusion. Application board for ZED-F9R
CMS	Collision Management System: The overall combination of preventative controls, mitigation, recovery and supporting controls, implemented by a mine site to prevent TMM collisions.
Controlled area	Area that is dedicated to testing with no interference from vehicular or pedestrian traffic. Example: Gerotek Test Facilities, section on mine isolated from any mining activity, or demarcated area at a TMM OEM assembly plant.
CPS	Collision Prevention System: A Product System that comprises the functionality and characteristics that comply with the RSA TMM collision prevention regulations. (TMM Regulations 8.10.1 and 8.10.2 and user requirements.)

CWAS/(CxD)	Collision Warning and Avoidance System device (CxD): Device with sensors providing collision warning and avoidance functions, to detect objects in the vicinity of the machine, assess the collision risk level, effectively warn the operator of the presence of object(s) and/or provide signals to the machine control system, to initiate the appropriate interventional collision avoidance action on the machine, to prevent the collision. Note to entry: Proximity Detection System (PDS) is a colloquial industry term for a physical device, providing a warning or collision avoidance functionality.
CxD	Collision warning/detection/management Device.
CxDC	CxD Controller: A sub-system of the CxD, that is typically the computer that contains the decision-making logic.
CxDI	CxD interface: A integration function between the CxD and the Machine Controller.
CxDLK	CxD Log Keeping: The function that receives, and stores CxD data.
D&T	Detect and Track: A functional group of a CxD enabling detection and tracking of TMMs and pedestrians inside the detection area of a surface TMM and an underground TMM respectively.
DAQ	Real time computer with data acquisition and control capabilities. Has ISO21815 interface. Example: DSpace MABX II.
Data scientist	Experienced person in the field of data processing and statistics. This person will analyse data collected during TRL9 pilot site roll-out testing.
Detection	Detection is sensing that an object has entered the detection area.
DMRE	Department of Mineral Resources and Energy.
Driver or operator reaction time (also known as perception response time)	The time that elapses from the instant that the driver recognises the existence of a hazard in the road, to the instant that the driver takes appropriate action, for instance, applying the brakes. The response time can be broken down into four separate components: detection, identification, decision and response. When a person responds to something s/he hears, sees, or feels, the total reaction time can be broken down into a sequence of components namely: • Mental processing time (sensation, perception / recognition, situational awareness, response selection and programming). • Movement time, and • Driver response time. Driver reaction time is also affected by several issues such as visibility, operator state of mind (fatigue), and direction or position of perceived danger.

EAV	Exposure Action Value
ELV	Exposure Limit Value
EM engineer	Qualified person (BEng, BTech) in the EMC environment, with extensive experience in EMI/EMC testing.
EMC	Electromagnetic Compatibility
EMESRT	Earth Moving Equipment Safety Round Table
EMI	Electromagnetic Interference
Employee	Employee means any person who is employed or working at a mine.
EW (Surface)	Effective Warning: For surface TMMs: The expected outcome of the operator action is that the potential collision is prevented, therefore an effective warning must inform the operators of both TMMs what the appropriate action(s) are, to prevent the potential collision.
EW (Underground)	Effective Warning: For Underground TMMs: The expected outcome of the operator and pedestrian action is that the potential collision is prevented. Therefore, an effective warning must inform the operators of TMMs what the appropriate action(s) are to prevent the potential collision and must alert the pedestrian to potential collisions, or interactions with TMMs in the vicinity.
F	Function: Indicates a function of the CPS or functional group.
F&TPR	Functional and Technical Performance Requirements
FMECA	Failure Mode Effect and Criticality Analysis
FTS	Fail to Safe: The functionality that will bring a TMM to a controlled stop
Functional Specification	Specifications that define the function, duty, or role of the product/system. Functional specifications define the task or desired result, by focusing on what is to be achieved, rather than how it is to be done.
G	General: Indicates a general requirement that is applicable to the entire CPS and all of it elements, modules, and components.
High Risk Running Period	A period when a mine change over from one brand or model of cap lamp to another. The changeover cannot be done in one shift. The period of changeover is considered to be a High-Risk Running Period.
Homologation	Homologation means to sanction or "allow." Homologation refers to the process taken to certify that a TMM fitted with a CPS is manufactured, certified, and tested to meet the standards specified for critical safety related devices fitted to TMMs.
HP GNSS	High Precision Global Navigation Satellite System, capable of measuring position, with an absolute accuracy of 0.1m and velocity to within 0.2km/h with an update rate of 100Hz. Example Racelogic VBOX 3i.
ICASA	*Independent Communications Authority of South Africa*
ICMM	International Council on Mining and Metals.

ICNIRP	International Commission on Non-Ionizing Radiation Protection
ID	Identifier.
Independent	Separate from the CPS product developer. Note: Independent does not imply an accredited 3rd party, although where required by local or international standards, it includes accredited 3rd parties.
Independent person	A person, typically a test-, software- or EM engineer, who is not affiliated with the CPS provider or TMM OEM, that can provide an unbiased assessment.
Integrated Testing Regime	A holistic method of testing, optimising existing testing facilities that are currently available irrespective of who owns them. This method ensures specific CPS tests are only done once (CxD and TMM CPS Product combinations) and verification is done as early as possible in the development process.
Interface	A boundary across which two independent systems meet and act on or communicate with each other. Four examples are: 1. CxD-machine interface – The interface between a Collision Warning and Avoidance System Device (CxD) and the machine. This interface is described in ISO/DTS21815-2. 2. The user interface – Also sometimes referred to as the Graphic User Interface (GUI) when an information display is used. This is the interface between the user (TMM operator or pedestrian) and the CxD or pedestrian warning system. 3. V2X interface – the interface between different CxD devices. 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-infrastructure (V-E). 4. CxD-peripheral interface – This is an interface between the CxD and other peripheral systems that may be present on the TMM. Examples include a fleet management system, machine condition monitoring system, or fatigue management system. Note: An interface implies that two separate parties (independent systems), are interacting with each other, which may present interoperability and/or EMI and EMC challenges.
LO	Local Object: Denotes the TMM that is detecting other TMMs (S) or pedestrians (P)
Localization	Localization is measuring the position of the object within the detection area; it provides the local object with a map of the remote objects within the environment.

Loss of control	The uncontrolled movement of a TMM due to operator, machine, or environmental reasons. Note: Section 8.10.3 of MHS Act. Loss of control may result in several scenarios: • Machine failure – park brake, or service brake, or tyre blowout. • Operator disabled – fatigue, medical condition, inattention, distraction, or non-compliance with TMP rules (e.g., over speeding on decline, or overloading)
MBS	Machine Braking System: The physical components that makes an unintelligent TMM intelligent and enables the CPS auto slow-down and stop functionality.
MC	Machine Controller.
MCI	Machine Control Interface: The interface between the Machine Controller and the CXD interface.
MHS Act	Mine Health and Safety Act No. 29 of 1996 and Regulations.
MHSC	Mine Health and Safety Council.
Minerals Council	Minerals Council South Africa.
MLK	Machine Log Keeping: The function that receives, and stores TMM CPS data.
MOSH	Mining Industry Occupational Safety and Health.
MRAC	Mining Regulations Advisory Committee.
MRL	Manufacturing Readiness Level. A manufacturing maturity level within a manufacturing readiness framework.
MS	Machine Sensing: Sensing functionality on a TMM that enable a fully functional CPS.
Multipath	Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths, typically some direct signals, but also some reflected signals. 
OWS	Operator Warning System: The system that provides the effective warning and other warnings to the operator of a TMM.
PDS	Proximity Detection System – see CxD.
Pedestrian	A person lying, sitting, or walking rather than travelling in a vehicle.
Project	Industry Alignment on TMM Collision Management Systems Project: CAS READINESS PHASE.

PWS	Pedestrian warning System: The system that provides the effective warning to pedestrians.
Quality Assurance	Verifying a process, product, or service; usually conducted by an experienced person in the specific field.
Reasonably practicable measure	Reasonably practicable means practicable with regards to: (a) The severity and scope of the hazard, or risk concerned. (b) The state of knowledge reasonably available, concerning the hazard or risk, and of any means of removing or mitigating the hazard or risk. © The availability and suitability of means to remove or mitigate that hazard or risk, and (d) The costs and the benefits of removing or mitigating that hazard or risk.
Reliability (sensor)	Sensor reliability refers to the consistency of a measure. Achieving the same result by using the same methods under the same circumstances, is considered a reliable measurement.
RO	Remote Object: Denotes TMM(s) (S) or pedestrian(s) (U) being detected by the LO.
Robustness (sensor)	Sensor robustness is the ability of the sensing device (sensor), to remain functional in the presence of normal operating conditions of TMMs on a mine, such as electromagnetic interference, mechanical vibration, dust, adverse weather conditions, etc.
S	Surface: Indicating that a specific aspect is applicable to surface TMMs/operations.
Safe Park	A way that a TMM is parked, namely: Machine static, engine switched of and park brake applied.
Safe speed	The speed that will ensure the controlled stopping of a TMM without any immediate negative impact on the operator or machine. Note: This is a conditional variable value, depending on multiple input variables.
SAMI	South African Mining Industry.
Sensor fusion	Sensor fusion is the process of combining sensory data, or data derived from disparate sources, such that the resulting information has less uncertainty than when the sources were to be used individually.
Significant risk (of collision)	The reasonable possibility of a TMM collision, given all the controls that a mine has put in place to prevent a TMM collision.
Slow down	ISO/TS 21815-2: 2021 defines slow down as: "The SLOW-DOWN action is sent by the CxD to reduce the speed of the machine in a controlled / conventional manner, as defined by the machine control system. The intent of this command is to slow down the machine when the CxD logic determines that a collision / interaction can be avoided by reducing speed".
SME	Surface Mobile Equipment (Surface TMMs)

Software engineer	Qualified person in the communications/computer environment, with extensive experience in ISO 21815 – 2:2021 programming and testing.
SP GNSS with self-recorder	Standard Precision Global Navigation Satellite System: A system that is capable of measuring position with an accuracy of 1.5m, with an update rate of 10Hz. Can also store its own data. Example: UBlox C102-F9R.
Stage gate	A step in the testing regime / process where the CPS product system is tested against acceptance criteria, the failure of which would limit the CPS product system from moving to the next step in the regime / process.
Stop	ISO/TS 21815-2: 2021 provides for two definitions, an emergency stop, and a controlled stop, both of which are a 'Stop'. The definitions are: 1. "The EMERGENCY-STOP action is sent by CxD to instruct the machine to implement the emergency stop sequence defined by the machine control system. The intent of this command is to stop the machine motion as rapidly as possible, to reduce the consequence level, if the CxD logic determines that a collision is imminent. The equivalent of an emergency stop is the operator slamming on the brakes in an emergency." 2. "The CONTROLLED-STOP action is sent by CxD to instruct the machine to implement the controlled stop sequence, defined by the machine control system." The intent of this command is to stop the machine motion in a controlled / conventional manner, when the CxD logic determines that a collision / interaction can be avoided by slowing down and stopping. The equivalent of a controlled stop is slowing down and stopping when approaching a red traffic light.
System	A combination of interacting elements organized to achieve one or more stated purposes (ISO/IEC/IEEE 2015).
T	Technical: Indicates a technical requirement of the CPS or functional group.
Technical specification	Specifications that define the technical and physical characteristics and/or measurements of a product, such as physical aspects (e.g. dimensions, colour, and surface finish), design details, material properties, energy requirements, processes, maintenance requirements and operational requirements.
Technician	Competent person with testing experience in the mining / vehicle environment, e.g. testing technician, TMM OEM technician, CxD technician, auto electrician, etc.
Test engineer	Experienced person in the engineering/mining environment with extensive experience in CPS testing.
This document	CPS Accelerated Test Plan

TMLP	Traffic Management Leading Practice: The MOSH Traffic Management Leading Practice for Open Cast/Cut mines in South Africa.
TMM	Trackless Mobile Machine. (Machine, vehicle, etc.)
TMM CPS	The functional group comprising all TMM CPS related functions.
TMM CPS Product	The product that will make a non-intelligent TMM intelligent and CxD ready.
TMM OEM	Original Equipment Manufacturer of TMMs. Original Equipment Manufacturer of a TMM may be the organisation which originally supplied, or last rebuilt, or modified the TMM, or the supplier per section 21 of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996).
TMP	Traffic Management Plan: A document that defines the traffic management system that a mine employs to ensure the safe movement of TMMs and pedestrians on the mine.
Tracking	Tracking is the monitoring of the progress of the objects in the detection area over time.
TRL	Technology Readiness Level: A technology maturity framework for measuring and monitoring technology maturity in 9 increasing levels from TRL 1 to TRL 9.
U/UG	Underground: Indicating that a specific aspect is applicable to underground TMMs/operations.
UTC	Coordinated Universal Time.
V2X	Vehicle to anything.
V2XIF	Vehicle to anything interface
Vicinity (Surface TMMs) Vicinity (Underground TMM and pedestrians)	The distance/time of two TMMs from the point of a potential collision, such that, if the operators of both machines are instructed to take action to prevent a potential collision, and one or both does not act, then the CPS will be able to prevent the potential collision. Note: Vicinity is a conditional, variable value, depending on multiple input variables. It is smaller than any value that is within the range of normal operation. The distance/time of a TMM from a pedestrian, such that, if the operator of the TMM and the pedestrian do not take action to prevent a potential collision, an emergency slow down and stopping of the TMM can be successfully executed, to prevent a potential collision between the TMM and the pedestrian. Note: Vicinity is a conditional, variable value, depending on multiple input variables. It is smaller than any value that is within the range of normal operation.
V-E	Vehicle to environment.
V-P	Vehicle to pedestrian.
V-V	Vehicle to vehicle.
Walking speed	In the absence of significant external factors, the average human's walking speed is 1.4meters per second. This is included to help define the crawl speed of vehicles.

WP 8	Work Package 8 CAS Readiness Criteria One of the work packages of the Industry Alignment on TMM Collision Management Systems Project: CPS READINESS PHASE
WP 9	Work Package 9: Testing protocols (including legacy equipment). One of the work packages of the Industry Alignment on TMM Collision Management Systems Project: CAS READINESS PHASE.

3. Context of this document

This document is part of the deliverable for Work package 8: Readiness Criteria, of the Industry Alignment on TMM Regulations Collision Management Systems Special Project of The Minerals Council South Africa: CPS TECHNOLOGY READINESS PHASE work.

The document will be released in 4 parts:

- Part 1 Functional Readiness.
- Part 2 Manufacturing Readiness
- Part 3 Operation Readiness. (this document).
- Part 4 Commercial Readiness.

4. Background

TMM regulations for the SAMI were promulgated in 2015. Some of the clauses related to diesel powered TMMs were suspended as a result of non-availability of technology to provide the functionality that is required to auto slowdown and stop the TMMs.

The Industry Alignment on TMM Collision Management Systems Special Project of The Minerals Council South Africa was initiated to facilitate the accelerated development of CPS products.

As a safety system that ultimately takes away the control of a TMM from an operator, specific functional requirements and manufacturing conformance criteria are needed in order to minimise the potential safety and production disruption emanating from the introduction of CPS products to the entire mining industry.

5. The CPS Life Cycle System (Ecosystem)

The CPS Life Cycle System (ecosystem) is defined in Part 1 of the CPS Readiness Criteria document. It is partially repeated here for purposes of context.

The CPS Life Cycle System is shown in figure 1.

CPS operational readiness relates to a mines readiness for introducing CPS products onto its TMMs, and into its mining processes. Operational readiness for introducing CPS on a mine, cuts across several CPS life cycle stages. Figure 1 shows the relevant operational readiness phases in relation to the CPS life cycle stages.

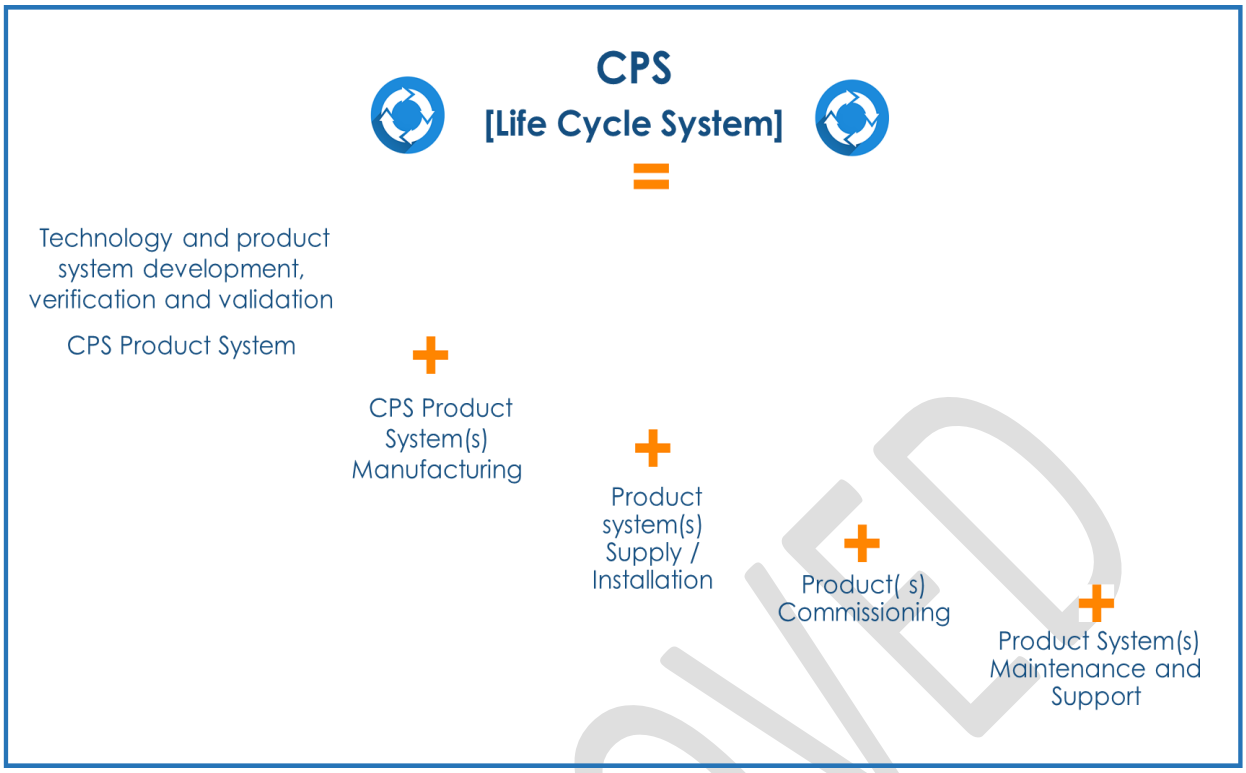


Figure 1: The CPS Life Cycle System

6. Approach to Operational Readiness Criteria

Collision prevention of TMMs (both V-V for surface and V-P for underground) in mining operations is a primary objective of South African Mine Health and Safety Act.

The interpretation of the TMM Regulations is documented in the CMS Technical Requirements Specification Guideline Review Report. It is partially repeated here for context.

General (Applicable to open pit/cast and underground mines)

The regulation states (8.10.1and 8.10.2) that: *The employer must take **reasonably practicable** measures to ensure that **pedestrians/persons** are **prevented** from being **injured** as a result of collisions between diesel powered trackless mobile machines and pedestrians/collisions between diesel powered trackless mobile machines. At any mine, where there is a **significant risk** of such collisions (collisions wherein pedestrians or persons can be injured) such measures must include…*

First consider **"reasonably practicable"**

Reasonably practicable with reference to the Act, which means practicable having regard to:

- the severity and scope of the hazard or risk concerned,

- the state of knowledge reasonably available concerning that hazard or risk and of any means of removing or mitigating that hazard or risk,
- the **availability and suitability** of means to remove or mitigate **(control)** that hazard or risk, and
- the cost of removing or mitigating that hazard or risk in relation to the benefits deriving therefrom.

Reasonable practicability involves weighing-up the risks and balancing these against the resources necessary to control them. (If risk is high, less weight can be placed on costs to implement controls than if risk is low.)

8.10.1 refers to … such measures shall include **at least** the following: At least can be defined as "not less than; as the minimum" – this clause may imply that CPS is the minimum that is required and that the mine must introduce controls other that CPS as well to prevent TMM collisions.

Consider "**prevent"**

Prevent means to stop something from happening or someone from doing something (prevent, avoid, stop, avert, prohibit, check). In terms of occupational health and safety management, prevent means the application of preventative controls that are either objects or systems.

Given the momentum involved when a TMM collides with a pedestrian, 'prevented from being **injured"** is almost impossible when a collision occurs. This is most likely the reason why the DMRE is so keen that employers introduce automatic stopping of **all** TMMs, as it will prevent TMM collisions with pedestrians as well as other TMMs.

Consider "**significant risk of collisions"**

The term "Significant" is defined in the Oxford Dictionary as being **"noteworthy**, of considerable amount or considerable effect or considerable importance".

The TMM COP guideline DMR 16/3/2/2-B2 issued by the Chief Inspector of Mines.

States:

The objective of this guideline is to enable the employer at every mine to compile a mandatory COP, which, if properly implemented and complied with, would improve health and safety in connection with the use of ***trackless mobile machines*** at a mine.

Section 11 of the MHSA requires the employer to identify and assess the health and safety **hazards** to which employees may be exposed while they are at work, and record the **significant hazards identified and risks assessed**. The **COP** must address how the **significant risks** identified in the risk assessment process **must be dealt with**, having regard to the requirements of sections 11(2) and 11(3) that, as far as reasonably practicable, attempts should first be made to **eliminate** the risk, thereafter, to **control** the risk at source.

The SAMRASS codebook defines **risk as "the likelihood that occupational injury or harm to persons will occur"** The above definition read together with "**prevent** collisions" and the reality that a TMM collision will most of the time result in an injury to a "pedestrian or a person" leads to the conclusion that **all** TMM collisions are "noteworthy" / significant and must be **prevented**.

A mine therefore must **identify all the places** on the mine where a TMM collision with a pedestrian or a TMM collision with another TMM is possible (respectively) and decide how collisions at that **specific** place will be "eliminated" and, if not eliminated, "addressed" i.e., what controls will be introduced to prevent the collision.

If the mine introduces **any** measures/controls to eliminate or prevent the collision at that specific place or the measures/controls that are introduced can prevent (are effective) that potential collision, then there is no "significant risk" that a collision can happen, and the mine does not have to introduce Collision Prevention Systems that will comply with the requirements of the regulations. Conversely if the mine does not introduce such measures/controls then the mine must introduce a CPS that complies with the requirements of the regulation, where there is significant risk, as per the traffic flow and risk analysis.

The inclusion of the **significant risk** condition into the regulations has a major implication for a mine as it provides the mine with an opportunity to not introduce CPS, but to introduce other controls to prevent TMM collisions.

Reading of the TMM CPS regulations in conjunction with the TMM Mandatory COP Guideline places an obligation on a mine to introduce **all** controls in accordance with the hierarchy of controls.

Operational Readiness for Collision Prevention Systems has several aspects that must be adequately addressed to ensure successful introduction of CPS products on the mine. These are:

- Traffic flow and risk analysis – Collision risk operations and areas.
- Collision prevention controls.
- TMMs requiring CPS.
- Procedures and standards.
- Maintenance competence and capacity.
- Technology selection.
- Spares Supply.

The Minerals Council MOSH Learning Hub has facilitated a Traffic Management Leading Practice Adoption Guide for Opencast/Pi Operations as well as a Traffic Management Guideline for Underground Trackless Operations.

The practice and guideline contain extensive guidance and effective controls that a mine must introduce as controls for collision prevention if adopting the practice or guideline. This document assumes that every mine in the SAMI has access to these guidelines/Leading Practice. It is further assumed that the introduction of the practice/guideline is part of the mine's commitment to implement the so called "low hanging fruits" whilst the CPS technology matures.

This document therefore does **not** repeat the content of either the Guideline or the Leading Practice. It however lists the specific aspects that must be completed to ensure timeous operational readiness.

Unlike for functional and manufacturing readiness an international Operational Readiness framework does not exist. The following practical framework will be used for structuring the operational readiness criteria:

- Phase 1 – Traffic Flow and Risk Analysis
- Phase 2 – Physical Collision Prevention Controls
- Phase 3 – Procedures and Standards
- Phase 4 – Technology selection
- Phase 5 – Maintenance and support.
- Phase 6 - Technology introduction

It is important to realise that the nature of the regulatory introduction of CPS requires an entire ecosystem to be ready. As such there are aspects that require industry wide solutions. Availability of the correct skills in terms of quantity and competence is not something that an individual mine can ensure. The Minerals Council acknowledged this and as a result the Industry Alignment on TMM Regulations; Special Project of The Minerals Council South Africa, addresses this specifically to assist mines to be operationally ready.

7. Phases of Operational Readiness

This section provides a brief description of each of the phases of operational readiness.

Phase 1: Traffic Flow and Risk Analysis

TMM collisions are priority unwanted events on mines that must be prevented. The basis of TMM collision prevention is visibility of the actual TMM potential interactions throughout all the mines' roads, operations, and operational areas.

The mine therefore needs to know the actual movement of all TMMs and pedestrians on the mine. Knowing who is going where, when, why and with what is the first step in the process. It provides visibility of the traffic flow on the mine over a period that represents the entry and movement of all TMMs on the mine as well as entering and exiting the mine. Specific emphasis must be put on the beginning and the end of shifts.

The most practical way for a mine to record the traffic flow is using survey plans, colour coded roads indicating specific TMM types working in production areas and on specific roads on the mine. By adding information tables to the survey plans the mine can manage the "As Is" and "To Be" traffic flows.

Typical information needed on the traffic flow survey plans are:

- TMM type, number of TMMs during normal operation as well as during shift changes, intersections, speed restrictions, road widths, etc. The survey plan

must indicate all the current and future berms (side berms, centre berms, slow down berms etc.)
- The pedestrian numbers and movement during the shift with particular emphasis on points of possible interactions with TMMs.

It is important to note that traffic flow analysis must be conducted over a period that represents all mining cycle types that are likely to occur and the aim is to achieve data saturation.

Traffic flow analysis can typically be carried out by:

- Identifying high risk areas with mine knowledgeable personnel and planning the traffic flow count and standing at those points and recording the traffic flow. Hint: photographic evidence of potential high-risk interaction assists in the risk assessment.
- For surface operations, flying drones and analysing the footage.
- Installing cameras and either using the drone footage or camera video footage for artificial intelligence analysis of the footage.

The risk analysis is the next step in the process. The risk analysis is not intended as a risk grading exercise. TMM collisions are unwanted events and must be prevented. The purpose of the risk analysis is to identify specific interactions and potential points of interaction between all TMMs and between TMMs and pedestrians (collision hot spots). All potential TMM interaction points must be indicated on the Traffic Flow survey plans.

The next step in the process is the application of collision prevention controls. Every specific collision hotspot must be evaluated and the effectiveness of the controls available, including those defined in Leading Practices and other traffic management guidelines and standard must be considered and the most effective controls must be selected for preventing potential collisions.

Phase 2: Physical Collision Prevention Controls
With all the collision prevention controls identified, this phase is to establish those controls physically on the mine. These might include LDV and HME separation, one directional flow, centre berms, intersection and ramp changes, hard park and workshop area layout changes and the like. This phase will most likely be the longest phase for the mine to get operationally ready as it requires a lot of physical construction work. This work will be the focus of a dedicated project or even projects that will require financial and human resource. Given the fact that the construction work might have to be done during operating hours it will require extensive execution risk assessment and co-ordination of resources or contractors to execute safely.

Phase 3: Procedures and Standards
This phase includes the updating of all CPS related standards, procedures and training materials, access control rules and procedures. A specific focus of this phase is the updating of the Mine's TMM CoP to include all the collision

prevention controls including the CPS requirements and references to standards and procedures. Depending on the mine's maturity with reference to traffic management this will be a key phase since it will embed the "new way of working" into the mines organisational system. This phase also includes all the preparation of the training and change management material to be used during later phases.

Phase 4: Technology Selection
On completion of phase 1 the mine will be able to identify where there will still be potential TMM collisions even with the effective controls to be introduced. The mine will therefore be able to identify the operations, areas, and roads where TMM collisions will still be possible and then identify all TMMs working in those areas, operations and roads. These TMMs will be the ones that will require CPS solutions. The list of TMMs (Type and model) must be submitted to the Minerals Council so that CPS products can be developed where feasible.

The mine must develop selection criteria as part of the scope of work for the selection of its technology provider(s). The criteria are to be part of the mine's procurement documentation.

As a result of a standardised V2X communication standard not being available and the mines decision to achieve a level of interoperability by using a single CxD product for every mine, the mine must also select the CxD product in collaboration with the TMM OEMs of its TMM fleet. The identified CxD provider must also be indicated to the Minerals Council for the purpose of collating the numbers of each type and model of TMM per OEM brand (determining the overall number of CPS's (combinations) that is required for the whole industry.

Phase 5: CPS Maintenance and Support
This phase of CPS operational readiness is to ensure that all maintenance and support arrangements and processes are in place such that the CPS can be introduced on the mine without any negative impact on production. It includes availability of the required skills whether inhouse or outsourced, spares supply etc.

The ecosystem skills work package has specific relevance to this phase and mines must ensure that they are fully aligned with what the eco system approach is and how they can benefit from it. This phase also includes the mines plan for establishing the required skills to support the CPS products. It is important that mines conclude phase 5 in time that all resources and spares are available at the start of the technology implementation phase.

Phase 6: Technology Introduction
Once the CPS products for the mine's TMMs that require CPS products are commercially ready, the mine can start with the introduction of the technology.

The MOSH Traffic Management Leading Practice provides extensive guidance for how this can be achieved. The content of the Leading Practice is not repeated

here as it is assumed that all mines have knowledge of and access to the leading practice, which can be accessed on the MOSH website.

The phase includes all the supply and logistic arrangement required for installation and commissioning of CPS products, training of TMM operators and pedestrians, change management initiatives and the like. Whist individual mines must be fully aware of the progress of the Industry Alignment on TMM Regulations; Special Project of The Minerals Council South Africa, mines must take note of the role of pilot mines at TRL 8 and TRL 9. Even where a mine is not a pilot mine the approach of TRL 8 will be beneficial for rolling out the CPS on the mine.

During this phase of operational readiness, the TMMs are installed with CPS products and commissioned. The mine verifies the effectiveness of the mines traffic management to prevent production loss due to potential emergency slow down and stop interventions as a result of an unoptomised traffic management system. The CPS is first activated without the automatic intervention functions and interaction hotspot analysis is done after every shift. Where the traffic management system requires further work, this is done, and it is confirmed that the hotspot has been resolved. Once the mine is sure that all the hotspots are resolved, the automatic intervention function are activated.

8. Operational Readiness Criteria for CPS introduction

Phase 1 Traffic Flow and Risk Analysis

Description of Activities	Success criteria (Evidence Description)
• Demarcation of mining processes and process boundaries • Identification of TMM and Pedestrian movement • Identification of potential collision hotspots. (Physical places) • Selection of the preferred CxD provider that the mine want to use for its fleet of CPS TMMs. This is needed to ensure that CxD providers know what TMMs their products must support. The mine must do the selection in conjunction with the relevant TMM OEMs.	• Updated mining lease area survey plan indicating process areas and boundaries. • Process area and road survey plans with TMM types that operate in the areas listed – primary, secondary and auxiliary TMMs. (haul trucks, loaders, drill rigs, personnel carriers. • List of TMM types models and numbers requiring CPS products identified and submitted to Minerals Council. • CxD provider submitted to Minerals Council. • Risk analysis documented and signed off • Collision Prevention Controls plan signed off.

Phase 2 Physical Collision Prevention Controls

Description of Activities	Success criteria (Evidence Description)
• Construction risk assessments • Physical construction of roadways, intersections, berms, access control and all other effective controls as per the updated risk analysis.	• All work as per plan completed and signed off by project manager. • "As built" survey plans, and workshop area block plans signed off by 3.1 legal appointee and all other relevant role-players.

Phase 3 Procedures and Standards

Description of Activities	Success criteria (Evidence Description)
• Operational Procedures harmonised with any new collision prevention controls including CPS products. Standards updated to include all collision prevention controls and provisions. • CoP updated, reviewed and approved including new or changed operator visibility diagrams as required by COP guideline.	• Collision Prevention related documentation list available and complete • All related documents reviewed and approved. • All documents available • TMM register updated to include CPS on each TMM • Operator visibility diagrams updated to include any visibility improvement as a result of the introduction of CPS.

Phase 4 CPS Technology Selection

Description of Activities	Success criteria (Evidence Description)
• Mine specific user requirement specification • Technology selection scope of work document development • Mine's standard commercial process activities	• CPS Products selected

Phase 5 CPS Maintenance and Support

Description of Activities	Success criteria (Evidence Description)
• Maintenance strategy, maintenance support agreements where relevant • Spares supply agreements	• Evidence of agreements and arrangements.

Phase 6 Technology Introduction

Description of Activities	Success criteria (Evidence Description)
• CPS product procurement and installation • Underground mines only: If new technology is selected, lamp room changeover plan and risk assessment. DMRE approval for the high-risk running period. • Change Management plan. • Section 21 files • Upgrading of unintelligent machines • Installation of CPS, commissioning, and testing • Effective reporting and follow up actions	• CPS acceptance certificate • DMRE record of approval for high risk running period • Change Management implemented • Section 21 files in place • Hot spot analysis and resolution • Effective reporting on interactions and overrides