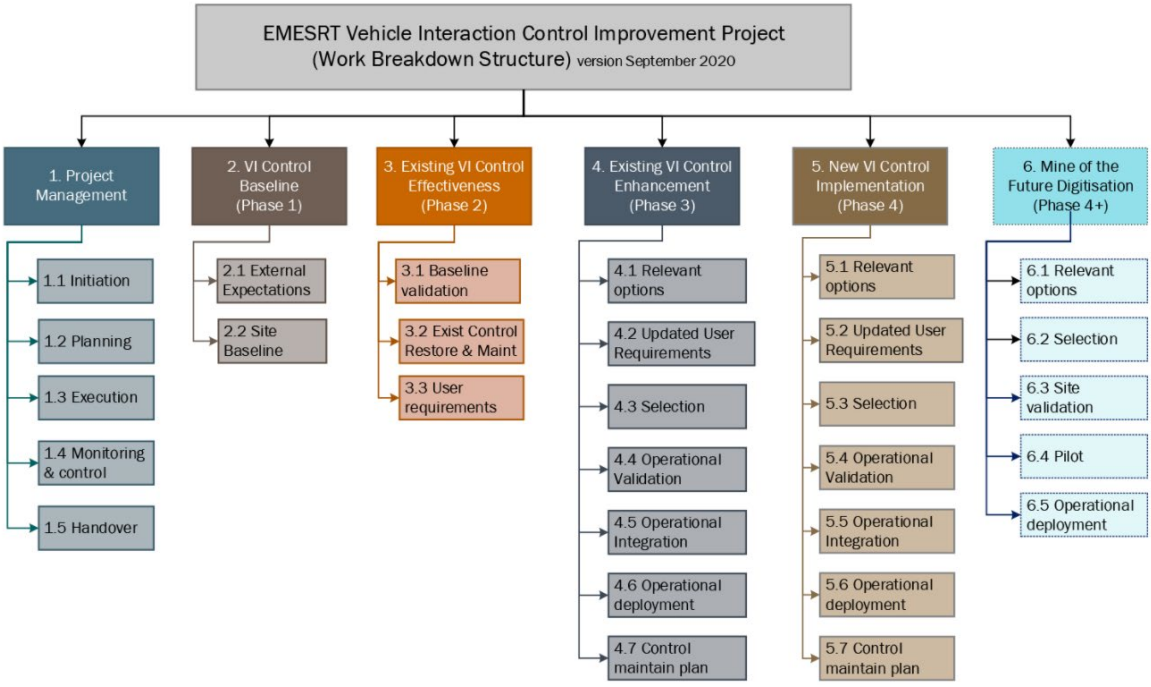
International Council on Mining and Metals
Innovation for Cleaner Safer Vehicles (ICSV)
Vehicle Interaction Stream
Maturity Framework Self-Assessment "How-To-Guide"

INTRODUCTION

The Vehicle Interaction Journey at your operation will be defined and implemented to suite your personal need and state of implementation. As with any project, understanding why Vehicle Interaction is an industry issue, asking the questions why you should change and what need to change as well as determining where you will find support, are all important milestones in your journey. The first, and most important milestone, will be that of understanding where you are on the Vehicle Interaction Maturity Framework. Below you will find a work breakdown structure that can typically be followed in your Vehicle Interaction Journey. The self-assessment step you are about to embark upon is part of the 1.1 initiation phase of your journey.



Reference - EMESRT VI Body of Knowledge

This document is designed to give guidance on the self-assessment process to be used to determine an operation's current and future desired status on the Vehicle Interaction (VI) Maturity Framework. It should be noted that this self-assessment is intended to encompass all vehicle and pedestrian interaction scenarios in both surface and underground operations. It can also be conditionally applied to processing plants.

VEHICLE INTERACTION VISION FOR 2025 – GUIDING PRINCIPLES

Intent of the Maturity Framework
The intent of the Maturity Framework is to Map, Motivate and Measure the intended status and journey for Vehicle Interaction (VI) Maturity. In addition, it will drive conversation at a site and amongst industry stakeholders to converge thinking, decision making and actions for the most effective use of technology to reduce the incidence of unwanted vehicle interactions in mining. Key intended outcomes include:

- Enabling member companies to move at their own, industry informed, pace.
- Providing a visual tool to assess progress at a site, company and industry level.
- Outlining an industry landscape on technological based controls already available or in development.
- Providing aligned industry thinking on functional requirements to stimulate OEMs and 3rd party innovation development.
- Enabling industry leaders to shift towards the ambition quickly (first adopters), bringing along fast followers and ultimately a collective industry shift.

The following is included / excluded in the scope.

- In scope
    - Surface and Underground, Vehicle Interaction – Machine to Machine, Machine to Person, Machine to Infrastructure and Loss of Control. The scope also includes all the mobile machines on site, including Light and Medium vehicles. Surface includes any area where vehicles interact, and a traffic management plan is implemented. It can also be conditionally applied to processing plants.
    - Manned vehicles operating in site with Autonomous vehicles.
- Out of scope
    - Autonomous Vehicles.

The self-assessment requires you to complete both the current and future state for 2025 and 2030. It will be beneficial for you to plot your desired state in order to understand where you are, where you want to be and to determine what the gap (next steps) is between these two states (refer to the maturity framework example below for reference). For the identified gap between current state and future state, reference can be made to the knowledge hub on case studies and lessons learnt from other operations.

The completed self-assessments will be collated and analyzed by ICMM. Results will be collated by:

- Whole industry
- Region (Europe, South America, North America, Africa, Australasia, Asia)
- Area of usage (Surface, Underground, Plant)

Aggregating the assessment beyond a site level provides no real value in determining next steps for a site and in fact may mask the real situations within a company.

Vehicle Interaction Systems

The definition of vehicle interaction system is taken from Earth Moving Equipment Safety Round Table (EMESRT) Performance Requirement (PR) 5A: Vehicle Interaction Systems (available

here). The objective is to prevent a person or equipment (machine or vehicle) causing an unwanted event in the following four categories resulting in injury or equipment damage:

1) Equipment to Person,
2) Equipment to Equipment,
3) Equipment to Environment, and
4) Loss of control of Equipment

by means of timely, repeatable, dependent and accurate information being presented to a person, the operator or the equipment itself so that appropriate action can be taken by the person, the operator or the equipment itself to avoid or mitigate the outcomes of the above unwanted events.

Understanding of the true intent of the requirements of each of the Levels 1-9 is significant in determining the current and desired states of Vehicle Interaction (VI) Maturity at an operation.

Level 1-6 – Operational Systems Controls

Underlying mine system of operations that may include utilizing technologies that enhance the existing control effectiveness e.g. fatigue detection.

Level 7 – Operator Awareness

Technologies that provide information to enhance the operator ability to observe and understand potential hazards in the vicinity of the equipment.

- Ability to provide enhanced situational awareness
- Alerts the operator to a potential abnormal situation
- Provides context of the situation to the operator
    - Where is it?
    - What is it?
    - How far away is it?
    - What is its heading?
    - How fast is it going?
- Supports visual confirmation for the operator.

Level 8 – Advisory Controls

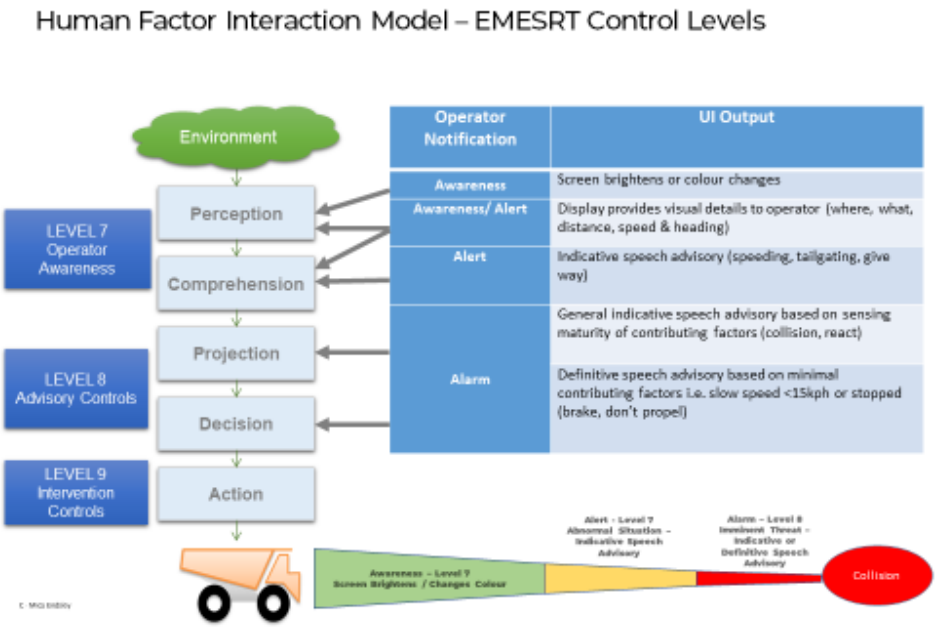
Technologies that provide alarms and/or instruction to enhance the operator ability to predict a potential unsafe interaction and the corrective action required:

- Determines an imminent threat of collision
- Provides a specific instruction to the Operator to intervene (Act)
- Operator assesses the instruction in relation to other contributing factors then intervenes (Acts).

Level 9 – Intervention Controls

Technologies that automatically intervene and take some form of equipment control to prevent or mitigate an unsafe interaction:

- Provides a specific instruction to the Machine to intervene (Act)
- Machine assesses the instruction in relation to other contributing factors then intervenes (Acts)
- Relinquish intervention control to the operator should they take evasive action
- Provides a manual over-ride to recover after a collision intervention scenario has occurred.



The mining industry is in the early adoption phase of automation technology. For many reasons including life of mine, economics and social license to operate, many mines will continue to run vehicles with a driver. Given that there are going to be staffed mines, then there are four ways to mitigate and/or eliminate unwanted interactions.

1. **Reduce people from interacting with vehicles.** This can be done by careful evaluation of roles and processes which require entry into areas where vehicles are operating. Technologies such as sensing/monitoring equipment can reduce the occurrence for engineering and operational personnel to enter the operating areas of the mine.

2. **Mine and road design.** There are many reasons why personnel must enter operating area, therefore design and layout of roads and zoning such that interaction with mobile machines is reduced should be a high priority. This reduction can be through improvements in traffic management plans, with focus on dedicated LV roads, improved intersections, one-way traffic and investments in tunnels and bridges. Furthermore, the

interaction between manned and autonomous vehicles should be considered as they pose different risks.

3. **Inattention management.** Ensuring that people working in the mine are alert and managing fatigue and distractions with process and technology. Fatigue management technology has been available for some years and has shown to be effective at warning of operator fatigue and distraction.

4. **Vehicle Interaction Systems**. The last element is to use technology to prevent unwanted vehicle interaction. It must be emphasized that the first two underlying control layers should be people (reducing roles required to interact with vehicles), process (traffic management) and technology (fatigue and interaction), with technology being the layer when the first two fail.

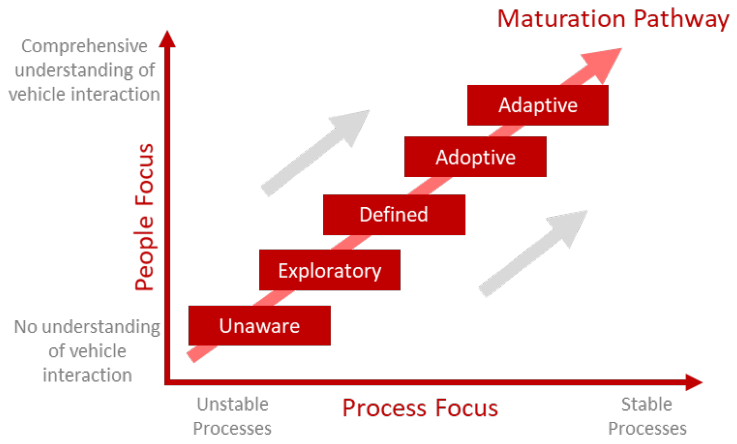
SELF ASSESSMENT GUIDELINES

Categorization

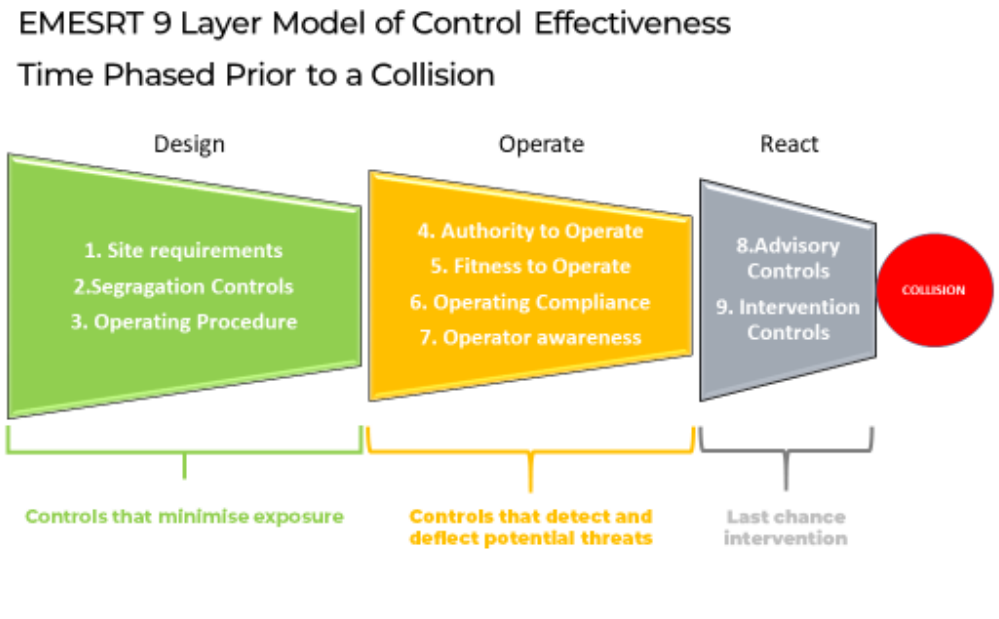
The categories of the self-assessment ranges from Unaware to Adaptive

i. Unaware –The operation has no awareness of vehicle interaction controls. Incidents are avoided through "luck" and not due to effective controls related to vehicle interaction.
ii. Explanatory –The operation has basic awareness of vehicle interaction related risks and controls. Time is spent on researching to gain more knowledge.
iii. Defined –The operation has awareness of vehicle interaction related risks, implementation of levels 1-7 controls and basic technology implemented to support 1-7.
iv. Adoptive –The operation has focused implementation of levels 1-7 controls and higher-level technology implemented to support / replace 1-7.
v. Adaptive – The operation has technology integrated systems approach to levels 1-9 to reduce exposure to ALARP (As Low As Reasonably Practical)

The 5-Stages in the Vehicle Interaction Maturation Pathway



The maturity framework strongly references the 9-layer model of control effectiveness developed by EMERST.



Self-Assessment Methodology

1. The maturity framework should be ranked to represent an operation's "current and future status" on Design Guidelines, Operational Controls and React Controls.
2. To further understand the requirements before awarding the ranking, consider the "Technical Guidance" at the end of this document. Current and future status of Design Controls should consider the current status of Levels 1, 2 and 3, Operate Controls should consider current status of Levels 4 to 7 and React Controls should consider current status of Levels 8 and 9. It remains important for the operation to understand the exact state of each of the 9 levels, but for assessment purposes amalgamate your response into the three categories.
3. Also complete the requirements in the company, commodity, country, mining fields and tonnage of material moved (millions of metric tonnes per annum) of each operation, as of 2020 or 2021, and available in the public domain.
4. The self-assessment requires you to complete the current and future state (in 2025 and 2030). It will be beneficial for you to plot your desired future state in order to understand where you are, where you want to be and to determine what the gap (next steps) is between these two states (refer to the maturity framework example below for reference).
5. For the identified gap between current state and desired state, reference can be made to the knowledge hub on case studies and lessons learnt from other operations.
6. Plot the required actions for each level to move from current state to desired state and list as the action plan. Your action plan need not be submitted with the completed maturity model.
7. Complete a separate surface and underground assessment for each operation within your company. It can also be conditionally applied to processing plants.

The VI Maturity Framework is available here on the ICSV Knowledge Hub including case studies and additional guidance. A copy is also provided in the excel self-assessment form.

TECHNICAL GUIDANCE

Use in conjunction with the VI Maturity Framework. The requirements of each block should be completely mastered to be considered. Should any of the requirements not be mastered, the compliance level of the block to the left should be used.

a. Design Controls

The main aim in the design phase is to DESIGN a site with the lowest possible unwanted vehicle interaction exposure. Pertinent points to consider in design controls include:

- Consideration of Vehicle Interaction exposure scenarios and controls in the design and layout of a new mine site. In the case of an existing mine, the consideration of amendments (as far as reasonably practical) to the design and layout of the existing mine, fully understanding that in some cases no changes can be made as the site may have been established and matured. In the case of a new mine, or where an existing mine can be altered, controls such as effective berms, access control, traffic segregation and time schedules will be specified that will minimize / eliminate exposure when vehicles interact. Examples of these controls include e.g. only one-way traffic to prevent vehicles from interacting, separating HME and LV traffic, design out the need for trucks to make U-turns or to have to reverse, etc
- Consideration of Vehicle Interaction exposure in establishing equipment procurement specifications in order to set a minimum standard for any vehicles that will be purchased
- Properly defined Safe Operating Procedures that are clear and concise, specify the road rules, maintenance rules and safety parameters.

b. Operational Controls

The main aim in the Operational Control phase is to define controls for operators to OPERATE within the space that was designed in the design phase, with the lowest amount of exposure. Pertinent points to consider in operational controls include:

- Strict rules and criteria on the minimum induction and training requirements, licensing and access control to the working environment
- Defined controls on the parameters for driver fatigue, substance abuse testing as well as systems that will ensure drivers are fit and healthy. These include systems to allow drivers to sleep properly, have rosters to ensure drivers have enough rest time and can be on full alert when behind the controls. Medical limitations should be defined for critical roles, which include screening for conditions that can impair performance
- Defining a suite of controls that will be mandatory before any equipment may be used such as pre-start controls, machine health, event recordings, etc.
- Technology considered that enhances the driver's ability to be situationally aware of or context of other vehicles / pedestrians in the vicinity that will have to be interacted with. Drivers operating large equipment cannot always see in all directions and therefore aids like cameras, additional mirrors, lights and visible delineators can assist the driver to

navigate around the vehicle. The main aim is to provide enhanced situational awareness for the driver of potential abnormal situations. The important aspect of Level 7 controls is that it provides the operator with information, but the operator can still choose to react on the information, or not.

c. React Controls

The industry is moving towards adding technology that allows the vehicle to REACT when the driver does not. This will include advisory controls (Level 8) and intervention controls (Level 9). Pertinent points to consider in react controls include:

- Advisory controls that take situational awareness one step further. It replaces some of the conventional controls in order to provide the driver with additional information about the surroundings, even where line of sight is not possible. These can include proximity detection, real-time fatigue operator event advice, monitoring of vehicle speed and stability, clearance such as tailgating etc. The important aspect of Level 8 controls is that it provides the operator with higher levels of situational awareness, but the operator can still choose to react on the information, or not.
- Intervention controls take control of specific vehicle functions, in an accident scenario, when the driver fails to react. This can also be referred to as anti-collision controls. These include retard and stop functionality, anti-roll-back functionality, speed control as well as controls that prevent the vehicle from starting up when the vehicle or operation may be exposed to an unwanted interaction. In Level 9 controls, the operator does have a window where a decision can be made whether to act or not, but if the driver does not react, the machine will intervene in order to prevent the incident.

SELF ASSESSMENT DATA

Selecting the assets

- Choose a number of assets in the portfolio to meet these conditions:
  - Each asset selected has large material movement relative to those in the portfolio
  - Each asset selected has a life-of-mine that spans the years of 2025 and 2030 assessments
  - Altogether the assets selected represent the range of commodities in the portfolio
  - Altogether the assets selected represent the range of regions in the portfolio (North America, South America, Africa, Australasia, other)
  - Altogether the assets selected represent a range of future states of maturity, i.e. include assets projected to be at the lower range, mid range, and higher range of the maturity scale.
- Submit data at the asset level, not at a regional level, commodity aggregation, or company-wide level.
- If the current state of an asset has been assessed in 2020 and has not changed since, simply input the data from the 2020 current state assessments into the Excel template.
- If selecting an asset whose current state was not assessed in 2020, assess its current state in addition to its future state.

Performing the assessment

- Use the December 2020 maturity framework available on the ICSV Knowledge Hub.
- If the conditions of a level are not fully satisfied, input the level one below the unsatisfied level. Do not use half level.
- Include the tonnage of material moved (millions of metric tonnes per annum) of each operation, as of 2020 or 2021, and available in the public domain.
- If an asset has more than one operation type (i.e. underground mining, surface mining, plant processing), use a distinct line for each operation type.
- If an operation type is assessed for VI, DPM and/or GHG, report VI maturity data on 1 line of the template and the GHG and/or DPM maturity data on another line.
- Assess the future maturity at years 2025 and 2030 for VI.

Submission of data to ICMM

- Use the Excel template to tabulate data as provided on the ICSV hub.
- Submit only 1 file per company.
- Submit the file no later than March 12, 2021, close of business GMT -6.
- Label the file *company name_2021 ICSV self-assessments.xls.*
- Send results to sarah.bell@icmm.com and sylvie.bouffard@icmm.com.