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EMESRT
Earth Moving Equipment Safety Round Table

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PR – 5A
Vehicle Interaction Systems

Revision history

Rev	Date	Description	Prepared by	Checked by	Approved by
1.0	April 2016	Initial performance requirement document developed	Susan Grandone Mining3	EAG	VI Working Group
2.0	August 2019	Reviewed and updated content	Neil Pollard Glencore	EAG	VI Working Group

Overview

This Performance Requirement (PR) has been developed to augment interpretation of EMESRT Design Philosophy (DP) 5, Machine Operation Controls in the following potential unwanted event (PUE) scenarios:

5.2 Injury due to workstation design and external structures
5.3 Injury or illness from physical and/or mental fatigue
5.4 Harm from impaired visibility (including distorted or degraded vision) or impaired awareness of hazards in a variety of operating conditions
5.5 Harm from restricted or impeded operator vision of the surrounding environment and for tool operation
5.6 Harm from collisions due to persons and small vehicles being encouraged/forced, by the equipment design, to locate on the operator's blind side
5.7 Harm from loss of machine stability while operating, tramming, articulating or relocating
5.8 Harm from incorrect use of equipment controls, incorrect/inaccurate calibration or ineffective maintenance due to poorly designed controls and displays
5.9 Harm from misinterpretation of information due to displays or labels
5.10 Harm, including mental overload, from warnings and alarms being overlooked, ignored or not heard

This PR should be read in conjunction with DP-5.

Performance Requirement Objectives

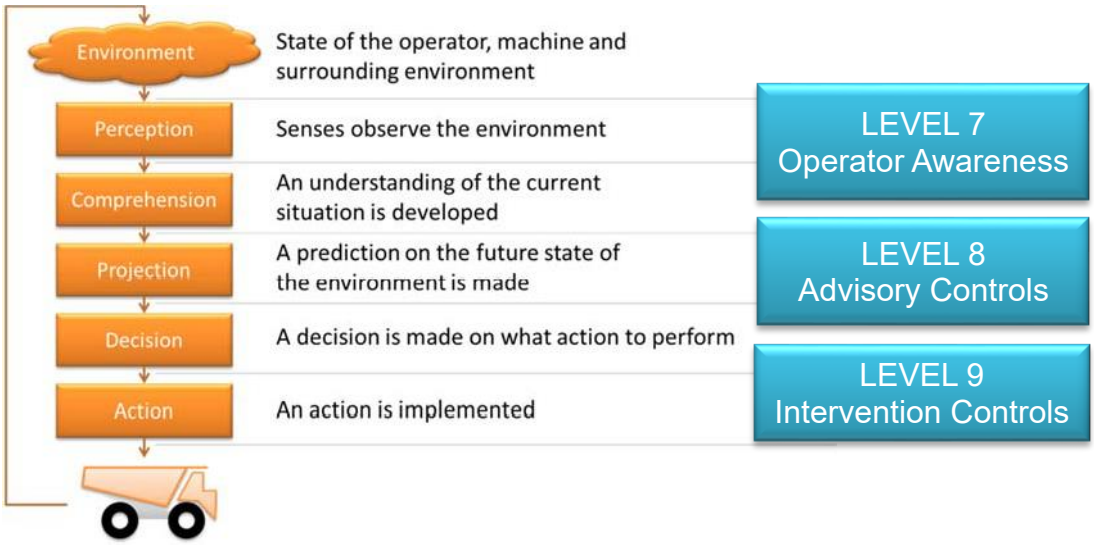
The objective is to prevent a person or equipment (machine or vehicle) causing a PUE in the following four PUE categories resulting in injury or equipment damage:

1. Equipment to person
2. Equipment to equipment
3. Equipment to environment
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 PUE's.

Operator Situational Awareness Model

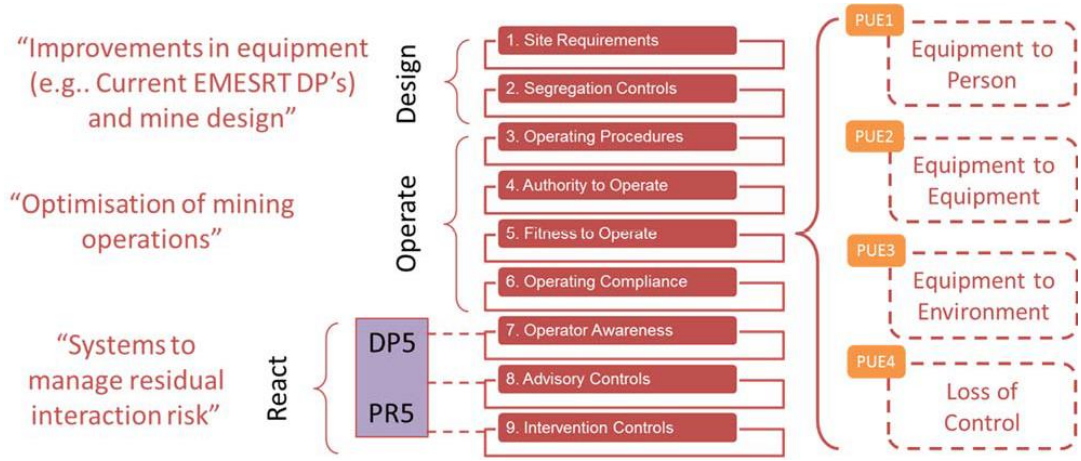
This Situational Awareness model depicts the key elements of operator interaction to control a vehicle effectively.



Model of Situational Awareness – Mica Endsley 1998

Vehicle Interaction Defensive Controls Model

The controls model depicts the 9 defensive layers which provide differing levels of process controls to prevent an unwanted vehicle interaction. The PR relates to the last three level of defence, 7, 8 and 9.



Control Classification Level Definitions

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

Design / Systems Interdependence

Given the range and brands of equipment in use in the mining industry and that there is an array of technologies and suppliers that may be utilised to meet the objectives of Levels 7, 8 and 9 designs, consideration of the differing systems/technologies interdependence will be a key requirement in design performance objectives.

Definitions

Local Object (LO): The interactor in the best position to avoid the interaction - generally the interactor with the highest energy. There is only one Local Object in any interaction and it must be capable of taking preventative action.

Remote Object (RO): The ‘other’ participant in the interaction, generally with limited preventative controls available

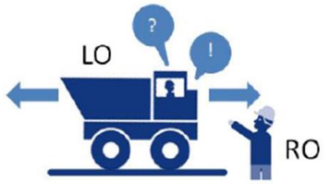
Vehicle Interaction Scenarios

The intended design outcome should include/consider but not be limited to the following interaction scenarios:

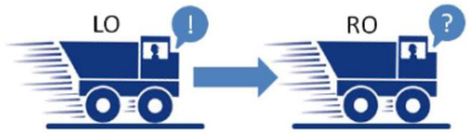
Scenario	Definitions
P1-Person (direct)	Person on foot (RO) in immediate vicinity around machine (LO)
P3-Person (indirect)	Person on foot that is a bystander in an interaction between machines and/or infrastructure
P4-Access and Egress	Person getting on or off stationary machine (see Access and Egress DP)
L1-Head-on	RO directly in the path of a LO moving (or intending to move) forward
L2-Backup	RO directly behind a LO moving (or intending to move) in reverse
L3-Reverse-on	Two machines (LO and RO) reversing towards each other
L4-Dovetailing	LO following a RO with both moving in the forward direction
L5-Passing Head-on	Two machines (LO and RO) passing each other in opposite directions with both moving forward
L6-Passing Reverse-on	Two machines oriented in same direction with the forward-moving LO passing a stationary or reversing RO
L7-Overtaking	LO pulling out and overtaking a RO with both moving forward
L8-Blind Approach	Forward-moving LO with limited or no visibility approaching a stationary or moving RO (blinded or obstructed)
C1-Curving Head-on	Two machines (LO and RO) approaching in opposite directions around a bend with both moving forward
C2-Curving Dovetail	Two machines (LO and RO) following each other around a bend with both moving forward
C3-Curving Reverse-on	LO approaching a stationary or reversing RO around a bend
T1-Merge	LO approaching a merge intersection with a RO travelling straight- through
T2-Crossover	LO intending to turn across path of oncoming RO
T3-Junction	LO approaching an tee intersection with RO travelling straight- through
T4-Intersection	LO approaching a ~90 degree four-way intersection with RO travelling straight-through
R1-Swing	Machine with rotating body (LO) operating with another machine (RO) near-by – e.g. shovel-truck
R2-Drop	Machine with elevated load (LO) transferring material to another machine (RO)
O1-Obstacle	Machine (LO) approaching a fixed object (RO) – e.g. high-wall, foot-wall, hanging-wall, infrastructure
V1-Void	Machine (LO) entering a no-go area (RO) - e.g. road or tip edge, limited clearance, soft barrier, electrical cable
V4-Loss of Control	Operator not in control of machine (LO) and none of the above scenarios apply (P1,P3,L1-8,C1-3,T1-3,O1,R1-2,V1)
V6-Congested Area	Machine (LO) operating with multiple (more than 2) other machines in close proximity – e.g. workshop area, LV/HV parking area

SURFACE VEHICLE INTERACTION SCENARIOS

P1-Person (direct)

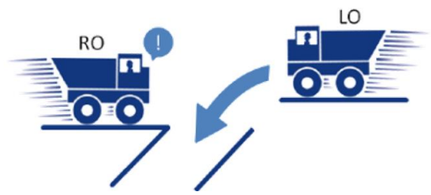


L4-Dovetailing



C1-Curving Head-on

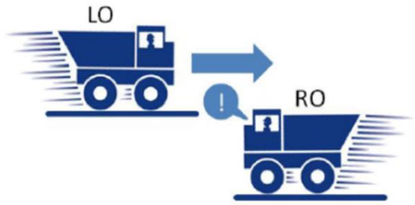
T2-Crossover



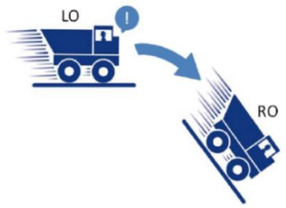
V1-Void

P3-Person (indirect)

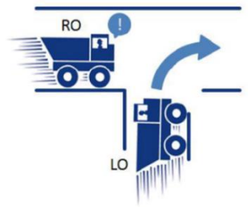
L5-Passing Head-on



C2-Curving Dovetail



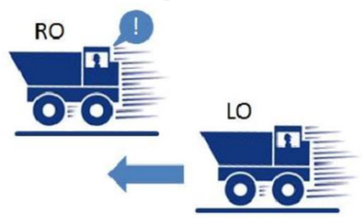
T3-Junction



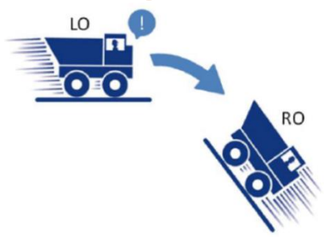
V4-Loss of Control

P4-Access and Egress

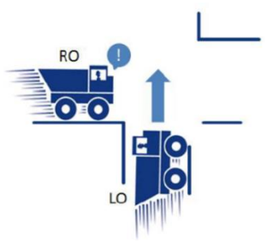
L6-Passing Reverse-on



C3-Curving Reverse-on



T4-Intersection



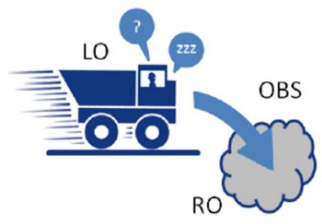
V6-Congested Area

L1-Head-on

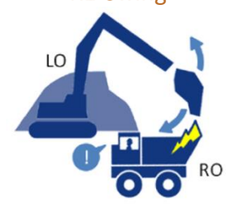
L7-Overtaking

T1-Merge

O1-Obstacle



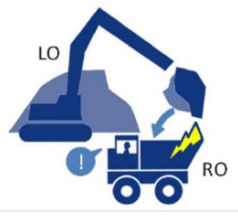
R1-Swing



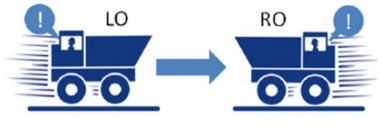
L2-Backup

L8-Blind Approach

R2-Drop

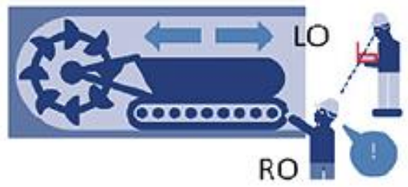


L3-Reverse-on



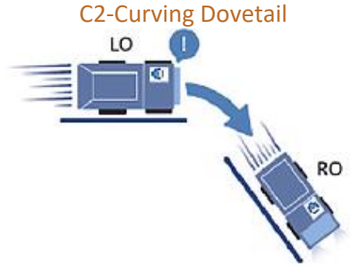
UNDERGROUND VEHICLE INTERACTION SCENARIOS

P1-Person (direct)

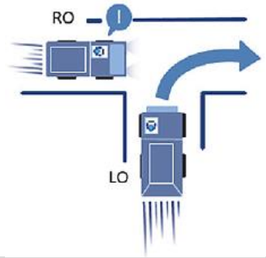


L4-Dovetailing

C2-Curving Dovetail

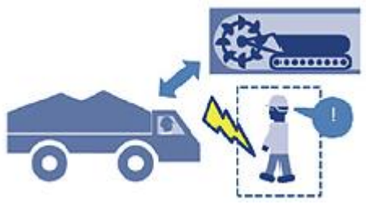


T3-Junction

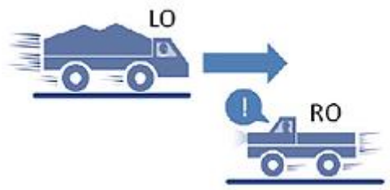


V1-Void

P3-Person (indirect)

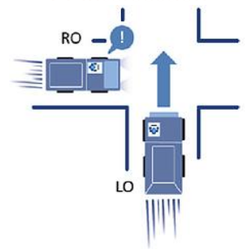


L5-Passing Head-on



C3-Curving Reverse-on

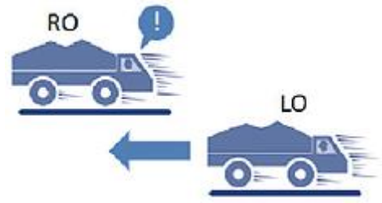
T4-Intersection



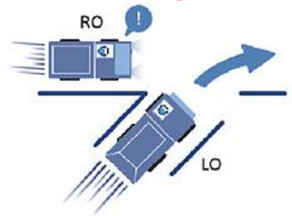
V4-Loss of Control

P4-Access and Egress

L6-Passing Reverse-on



T1-Merge



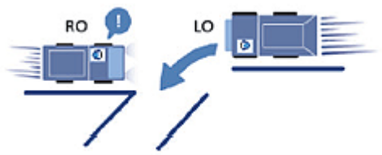
O1-Obstacle

V6-Congested Area

L1-Head-on

L7-Overtaking

T2-Crossover

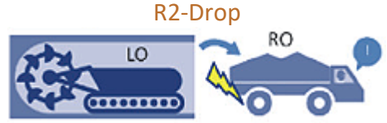


R1-Swing

L2-Backup

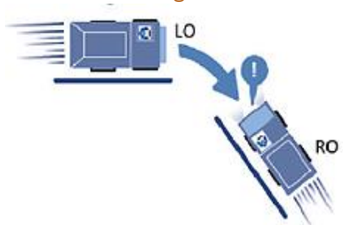
L8-Blind Approach

R2-Drop



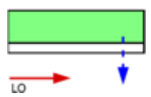
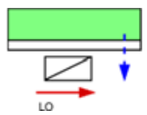
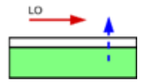
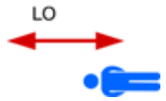
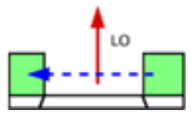
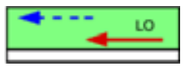
L3-Reverse-on

C1-Curving Head-on

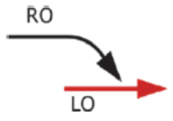
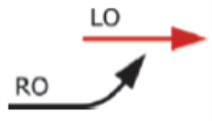
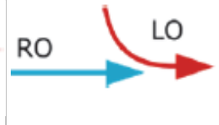
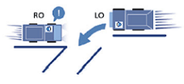
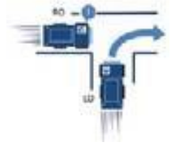
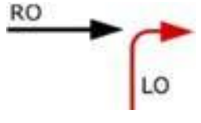
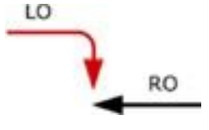
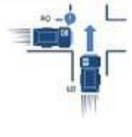


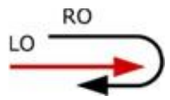
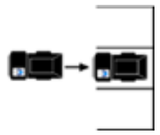
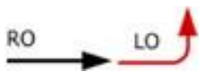
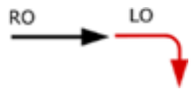
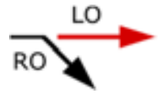
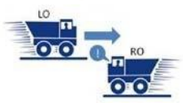
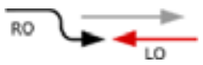
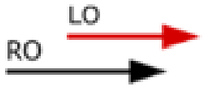
SCENARIO CODES – SURFACE

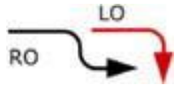
PUE 1 - Equipment to Person

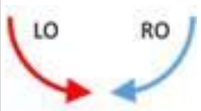
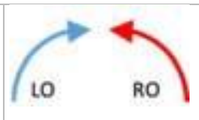
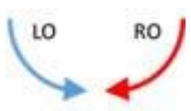
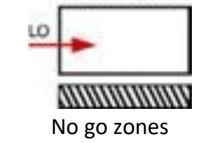
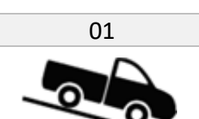
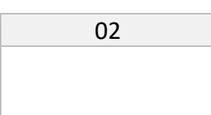
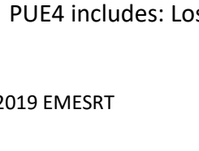
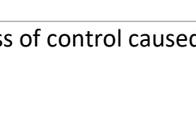
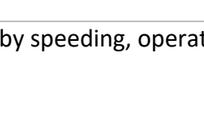
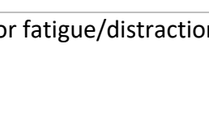
		01	02	03	04	05	06	07	08	09	XX
P1	P1-Person (direct) 	 Near-side	 Emerging	 Far-side	 Working lying, standing	 Walking with traffic	 Walking against traffic	 Driveway	 On walkway		Other
P3	P3-Person (indirect) 	 Spotting	 Materials handling	 Sprung, coiled energy release	 Suspended load	 Electrical contact	 Pressure release				Other
P4	P4-Access and Egress 	 Boarding	 Alighting	 Hot-seat change	 Training	 Falling off					Other

PUE 2 - Equipment to Equipment

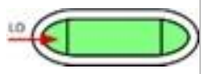
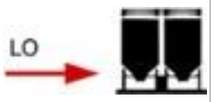
		01	02	03	04	05	06	07	08	09	XX
T1	T1-Merge 	 Left-Merge	 Right-Merge	 Merge-Left	 Merge-Right						Other
T2	T2-Crossover 	 Left-Crossover	 Right-Crossover	 Right-Left							Other
T3	T3-Junction 	 Right-Thru	 Straight-Right	 Right-Right	 Left-Right	 Straight-Left	 Right-Straight				Other
T4	T4-Intersection 	 Thru-Thru	Right-Straight								Other

L1	L1-Head-on 	 On-path	 U-Loop									Other
L2	L2-Backup 	 Reversing at park-up area	 Loading	 Reversing at dump								Other
L3	L3-Reverse-on 	 Reversing										Other
L4	L4-Dovetailing 	 Rear-end	 Left-Rear	 Right-Rear	 Pullout-Rear							Other
L5	L5-Passing Head-on 	 Head-on into oncoming path	 Misjudged clearance									Other
L6	L6-Passing Reverse-on 	 Lane incursion	 Pulling out	 Cutting in								Other

		01	02	03	04	05	06	07	08	09	XX
L7	L7-Overtaking 	 Pulling out	 Overtake-Right								Other
L8	L8-Blind Approach 	 Sun Glare	 Bright Light	 Reflection	 Rain / fog / snow / weather	 Mine or road design					Other

C1	C1-Curving Head-on 	 LO Cutting Corner	 LO Swinging Wide	 RO Oversteer	 RO Understeer						Other
C2	C2-Curving Dovetail 	 Outside Head- Tail	 Inside Head-Tail								Other
C3	C3-Curving Reverse-on 	 Outside Reverse- up	 Inside Reverse- up								Other
V6	V6-Congested Area 	 Enter park-bay	 Leave park-bay	 Door / ladder							Other

PUE 3 - Equipment to Environment

		01	02	03	04	05	06	07	08	09	XX
O1	O1-Obstacle 	 Reversing into object	 Permanent construction	 Temporary roadworks	 Temporary object on road	 Animal on road	 Drove into berm	 Drove into infrastructure	 Accident or breakdown		Other
V1	V1-Void	No go zones	Unstable ground								Other

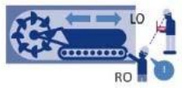
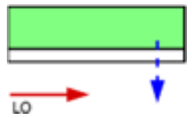
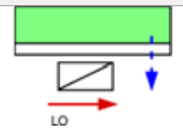
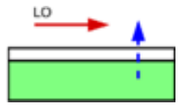
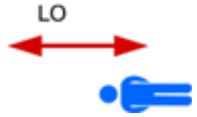
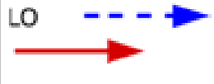
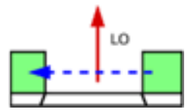
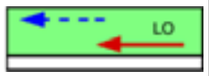
PUE4 - Loss of Control

		01	02	03	04	05	06	07	08	09	XX
V4	V1-Loss of Control	❖ Rollaway on road									Other

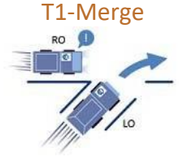
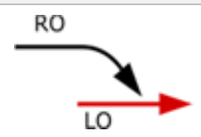
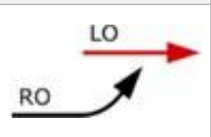
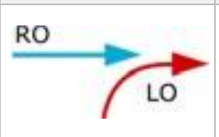
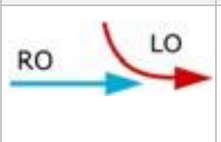
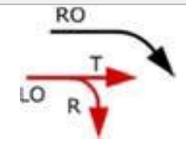
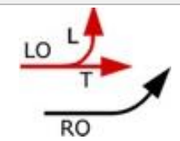
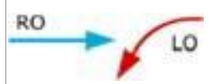
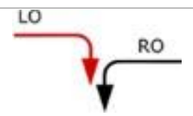
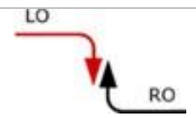
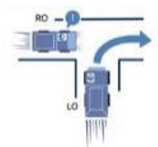
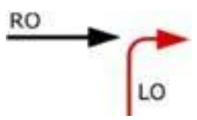
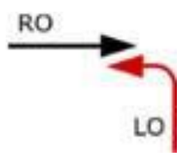
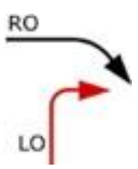
❖ PUE4 includes: Loss of control caused by speeding, operator fatigue/distraction, mechanical failure, watered road (manual/environmental)

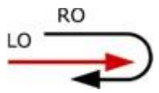
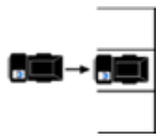
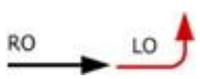
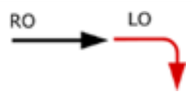
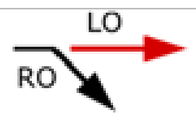
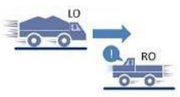
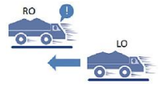
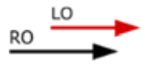
SCENARIO CODES – UNDERGROUND

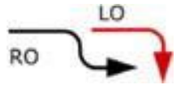
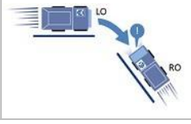
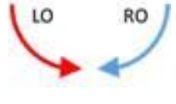
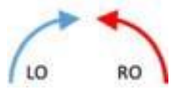
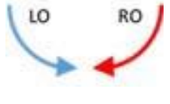
PUE 1 - Equipment to Person

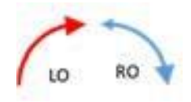
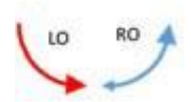
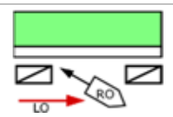
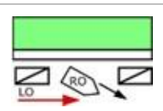
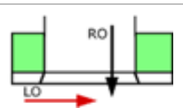
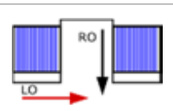
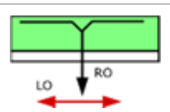
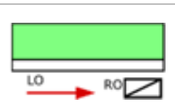
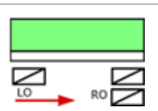
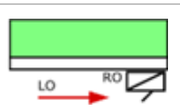
		01	02	03	04	05	06	07	08	09	XX
P1	P1-Person (direct) 	 Near-side	 Emerging	 Far-side	 Working lying, standing	 Walking with traffic	 Walking against traffic	 Driveway	 On walkway		Other
P3	P3-Person (indirect) 	 Spotting	 Materials handling	 Sprung, coiled energy release	 Suspended load	 Electrical contact	 Pressure release				Other
P4	P4-Access and Egress 	 Boarding	 Alighting	 Hot-seat change	 Training	 Falling off					Other

PUE 2 - Equipment to Equipment

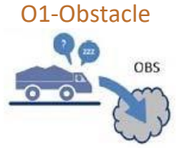
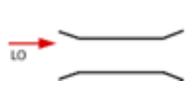
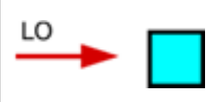
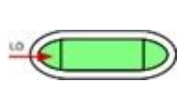
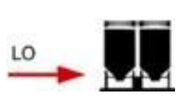
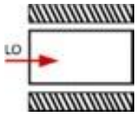
		01	02	03	04	05	06	07	08	09	XX
T1	T1-Merge 	 Left-Merge	 Right-Merge	 Merge-Left	 Merge-Right	 U-Turn	 Right-Swipe	 Left-Swipe			Other
T2	T2-Crossover 	 Left-Crossover	 Right-Crossover	 Right-Left	 Right-Right						Other
T3	T3-Junction 	 Right-Thru	 Left-Thru	 Thru-Right	 Right-Right	Left-Right	Thru-Left	Left-Left	Thru-Left		Other
T4	T4-Intersection	Thru-Thru	Right-Left	Left-Left	Right-Straight						Other

L1	L1-Head-on 	 On-path	 U-Loop									Other
L2	L2-Reverse-on 	 Reversing										Other
L3	L3-Backup 	 Reversing at dump	 Reversing at park-up area	 Loading								Other
L4	L4-Dovetailing 	 Rear-end	 Left-Rear	 Right-Rear	 Pullout-Rear							Other
L5	L5-Passing Head-on 	 Head-on into oncoming path	 Misjudged clearance									Other
L6	L6-Passing Reverse-on 	 Lane incursion	 Pulling out	 Cutting in								Other

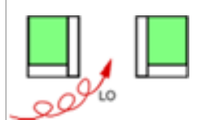
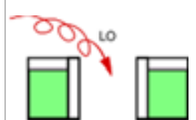
		01	02	03	04	05	06	07	08	09	XX
L7	L7-Overtaking 	 Pulling out	 Overtake-Right								Other
L8	L8-Blind Approach 	 Sun Glare	 Bright Light	 Reflection							Other
C1	C1-Curving Head-on 	 LO Cutting Corner	 LO Swinging Wide	 RO Oversteer	 RO Understeer						Other

C2	C2-Curving Dovetail 	 Outside Head- Tail	 Inside Head-Tail								Other
C3	C3-Curving Reverse-on 	 Outside Reverse- up	 Inside Reverse- up								Other
V6	V6-Congested Area 	 Enter park-bay	 In park-bay	 Leave park-bay	 Leaving driveway	 Loading bay	 From footway	 Limited space	 Double park	 Door / ladder	Other

PUE 3 - Equipment to Environment

		01	02	03	04	05	06	07	08	09	XX
O1	O1-Obstacle 	 Reversing into object	 Permanent construction	 Temporary roadworks	 Temporary object on road	 Animal on road	 Animal off road	 Load hits vehicle	 Drove into berm	 Drove into infrastructure	Other
V1	V1-Void 	 Accident or breakdown	 Maintenance area	 Unstable ground	 On rail tracks						Other

PUE 4 - Loss of Control

		01	02	03	04	05	06	07	08	09	10
V4	V4-Loss of Control 	 Operator not in control	 Out of control on straight road	 Off road to left	 Off road to right	 Off road to left into object	 Off road to right into object	 Lost control turning left	 Lost control turning right	Rollaway on road	Other
***V4** Continues*		11	12	13	14	15	16	17	18	19	XX
		Lost control into berm	Out of control on bend	Off road on right bend	Off road on left bend	Off road on right bend into object	Off road on left bend into object	Lost control on left bend	Lost control on right bend	Rollaway off road	Other

Vehicle Interaction Scenario Performance Requirement Definitions

		Control Type		
Potential Unwanted Event types	**General Requirements**	**(Level 7) Operator Awareness**	**(Level 8) Advisory**	**(Level 9) Intervention**
Equipment to person **People enter, or are in the at-risk zone of the machine**	Machine is in control by the operator The at-risk zone is mobile equipment type and closure speed dependent The system is active during machine start-up, running and shut-down	*Operator is made aware of people by:* ▪ Correcting a specific significant operator blind-spot ▪ Correcting multiple significant operator blind-spots ▪ Providing information on the presence of personnel in the at- risk zone ▪ Providing information on the location of personnel in the at- risk zone ▪ Providing information on the location of personnel in the surrounding area	*Operator is alerted to the presence of people by:* ▪ Alarming the presence of people in a significant operator blind-spot ▪ Alarming the presence of people in the at-risk zone ▪ Alarming the location of people in the at-risk zone *Operator is advised to undertake a prescribed action to avoid/mitigate a collision with people by:* ▪ Alarm with advice to prohibit specific actions ▪ Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate a collision with people by:* ▪ Modifying or limiting operator inputs for specific machine controls ▪ Modifying or limiting specific machine functions ▪ Asserting full control over the machine
Equipment to equipment **Equipment enters or is in the at-risk zone of the machine**	Machine is in control by the operator The at-risk zone is mobile equipment type and closure speed dependent The system is active during machine start-up, running and shut-down	▪ Operator is made aware of other equipment and vehicles by: ▪ Correcting a specific significant operator blind-spot ▪ Correcting multiple significant operator blind-spots ▪ Providing information on the presence of equipment and vehicles in the at-risk zone ▪ Providing information on the type, location, heading and speed of equipment and vehicles in the at-risk zone ▪ Providing information on the location, type, heading and speed of equipment and vehicles in the surrounding area	*Operator is alerted to the presence of other equipment and vehicles by:* ▪ Alarming the presence of other equipment and vehicles in a significant operator blind-spot ▪ Alarming the presence of other equipment and vehicles in the at-risk zone ▪ Alarming the type, location, heading and speed of equipment and vehicles in the at-risk zone *Operator is advised to undertake a prescribed action to avoid/mitigate a collision with mobile equipment or vehicles by:* • Alarm with advice to prohibit specific actions • Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate a collision with other equipment and vehicles by:* ▪ Modifying or limiting operator inputs for specific machine controls ▪ Modifying or limiting specific machine functions ▪ Asserting full control over the machine
Equipment to infrastructure, Object	Machine is in control by the operator The at-risk zone is mobile equipment type and closure speed dependent The system is active during machine start- up, running and shut-down	*Operator is made aware of infrastructure and objects by:* ▪ Correcting a specific significant operator blind-spot ▪ Correcting multiple significant operator blind-spots ▪ Providing information on the presence of infrastructure and objects in the at-risk zone ▪ Providing information on the type and location of infrastructure and objects in the at-risk zone ▪ Providing information on the type and location of infrastructure and objects in the surrounding area	*Operator is alerted to the presence of infrastructure and objects by:* ▪ Alarming the presence of infrastructure and objects in a significant operator blind-spot ▪ Alarming the presence of infrastructure and objects in the at-risk zone ▪ Alarming the type and location of infrastructure and objects in the at-risk zone *Operator is advised to undertake a prescribed action to avoid/mitigate a collision with infrastructure and objects by:* • Alarm with advice to prohibit specific actions • Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate a collision with infrastructure and objects by:* ▪ Modifying or limiting operator inputs for specific machine controls ▪ Modifying or limiting specific machine functions ▪ Asserting full control over the machine
Equipment to Environment *Loss of control includes loss of drive, traction, steering, braking, and stability due to adverse operating surface conditions* *Includes entry into prohibited areas*	Machine has been in control by the operator The at-risk zone is mobile equipment type and closure speed dependent The system is active during machine start-p, running and shut-down	*Operator is made aware of environmental conditions by:* ▪ Correcting a specific significant operator blind-spot ▪ Correcting multiple significant operator blind-spots ▪ Providing information on the conditions in the at-risk zone ▪ Providing information on the type and location of conditions in the at-risk zone Providing information on the type and location of conditions in the surrounding area	*Operator is alerted to the environmental conditions by:* ▪ Alarming the presence of adverse conditions in the at-risk zone ▪ Alarming the type and location of adverse conditions in the at-risk zone ▪ Alarming the type of loss of control *Operator is advised to undertake a prescribed action to avoid/mitigate the loss of control by:* ▪ Alarm with advice to prohibit specific actions Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate the loss of control by:* ▪ Modifying or limiting operator inputs for specific machine controls ▪ Modifying or limiting specific machine functions ▪ Asserting full control over the machine