SUOMEN AUTOMAATIOSEURA RY
FINNISH SOCIETY OF AUTOMATION

Turvallisuusjaosto ASAF

VTT

Autonomisten työkoneiden turvallisuus

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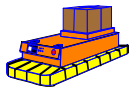
Autonomous ground vehicles

Autonomous vehicle	Typical safety measures, properties
Driverless car 	On-board safety systems; high speed
Autonomous mobile machine  	On-board safety systems, fleet management, area access control systems; moderate speed
Semi-autonomous mobile machine highly automated  	as above, in addition, human supervises actively the system; moderate speed
Automated guided vehicles (AGV), indoors applications  	On-board safety systems, area access control; slow speed, (closed structure cases, moderate speed)
Mobile robots 	On-board safety system, slow speed, used routes not definite, but the area is

Automated – autonomous – driverless – highly automated…

Levels of autonomy [Ref: The Society of Automotive Engineers SAE 3016]:
0: No automation - human control
1: Driver assistance - some functions automated
2: Partial automation - normal operations automated; human ready to take over
3: Conditional automation - safety-critical functions automated; human present
4: High automation - full autonomy of safety-critical functions and environmental monitoring for duration of trip
5: Full automation - full autonomy with no human-available control interfaces

Driverless industrial truck: powered truck, designed to operate automatically to transport loads. [ISO/DIS 3691-4:2018]
Autonomous machine: mobile machine that is intended to operate in autonomous mode during its normal operating cycle [ISO 17757:2017]
Machine allowing highly automated operation: machine which a) has functions are controlled by a control system without direct human input from local or remote operator b) does not require an on-board operator for primary control c) does or does not include an on-board operator station d) is subject of supervision. [ISO/DIS 18497.2:2016. Agricultural machinery and tractors — Safety of highly automated agricultural machines — Complementary element]
Self-driving car: A computer-controlled car that drives itself [PC Magazine].
Autonomous vehicle: a vehicle capable of navigating district roadways and interpreting traffic-control devices without a driver actively operating any of the vehicle's control systems. [Washington, DC's district code] - Autonomous vehicle means a motor vehicle that is equipped with an automated driving system which is designed to function at a level of driving automation of level 3, 4 or 5 pursuant to SAE J3016. The term includes a fully autonomous vehicle.[Statutes of Nevada. NRS 482A.030]
An unmanned ground vehicle (UGV): a vehicle that operates while in contact with the ground and without an onboard human presence. [Wikipedia]
An **automated guided vehicle** or automatic guided vehicle (**AGV**)(IGV intelligent …) is a portable robot that follows along marked long lines or wires on the floor, or uses radio waves, vision cameras, magnets, or lasers for navigation. [Wikipedia]

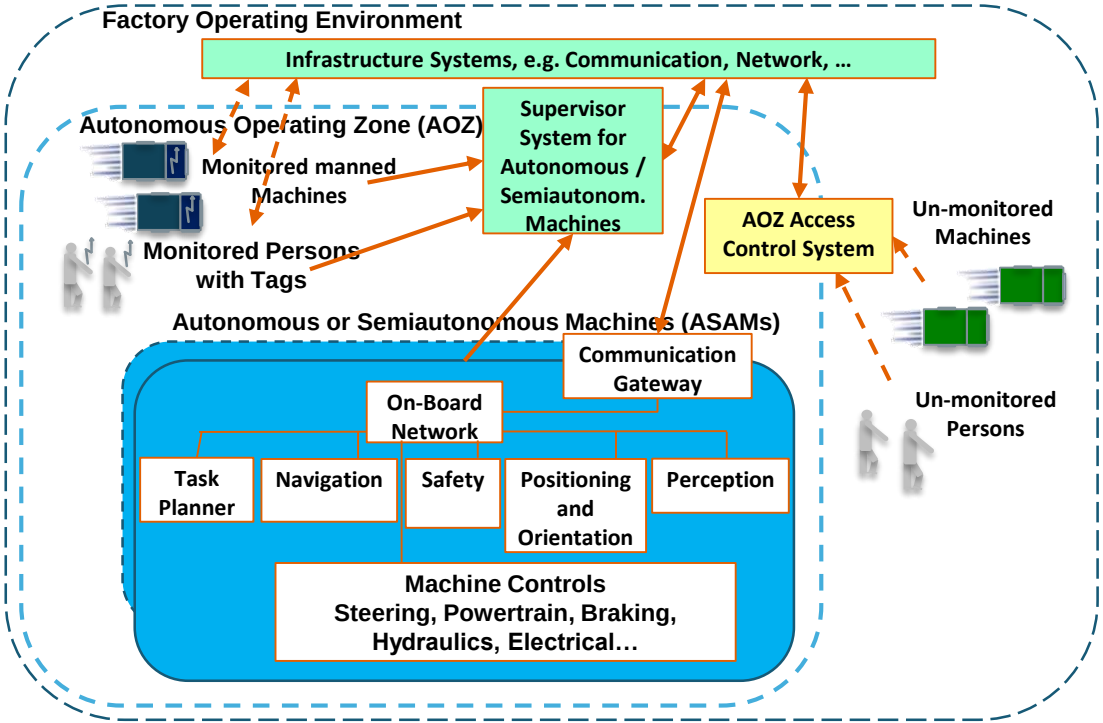
Autonomous and semi-autonomous machine system ASAMS

Autonomisen työkonejärjestelmän osat

Autonomous operating zone is for autonomous operations.

Area access control(s) – change the operation mode of the area when a person enters it.

Only monitored persons/vehicles may operate at the autonomous operating zone during normal automated/autonomous mode.

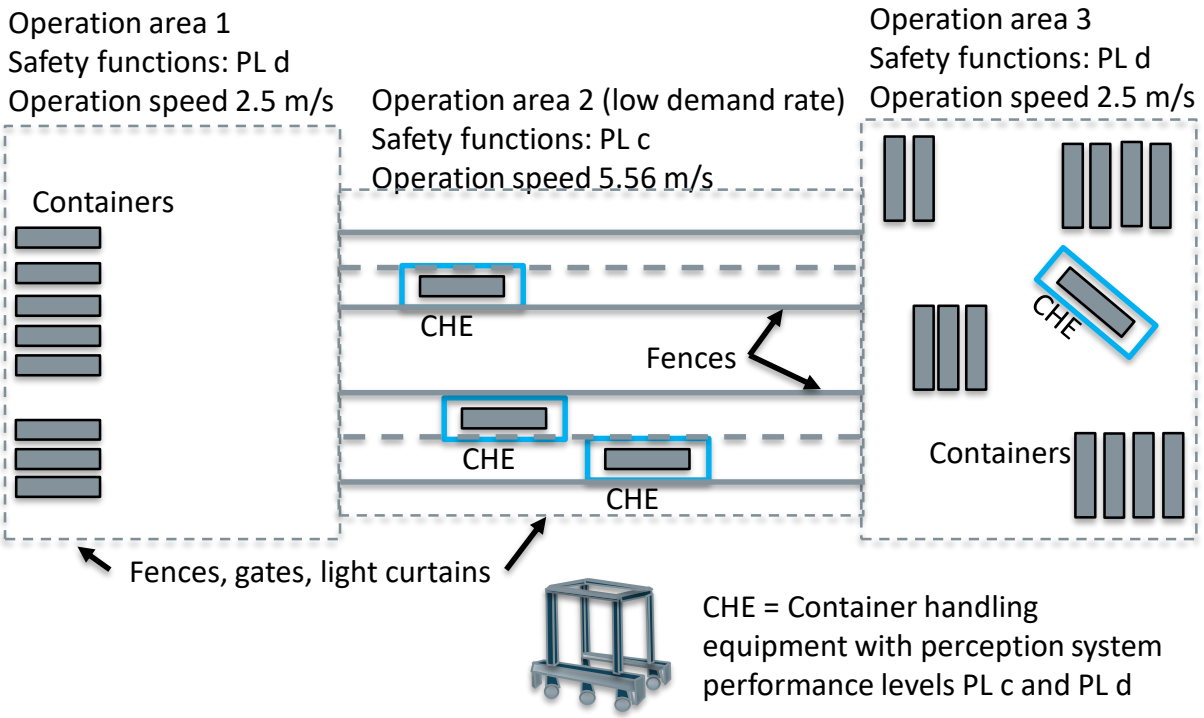


Ref: ISO 17757:2019. Earth-moving machinery and mining — Autonomous and semiautonomous machine system safety. 36 p.

Example fro IEC/TR 16998-2:
Container handling equipment for harbour logistics 1

Autonomous machine system Area is divided into three zones, which have different requirements (e.g. speed, PL)

Area access control system allows authorized access or stops the system if there is unauthorized access.



Example fro IEC/TR 16998-2:
Container handling equipment for harbour logistics 2

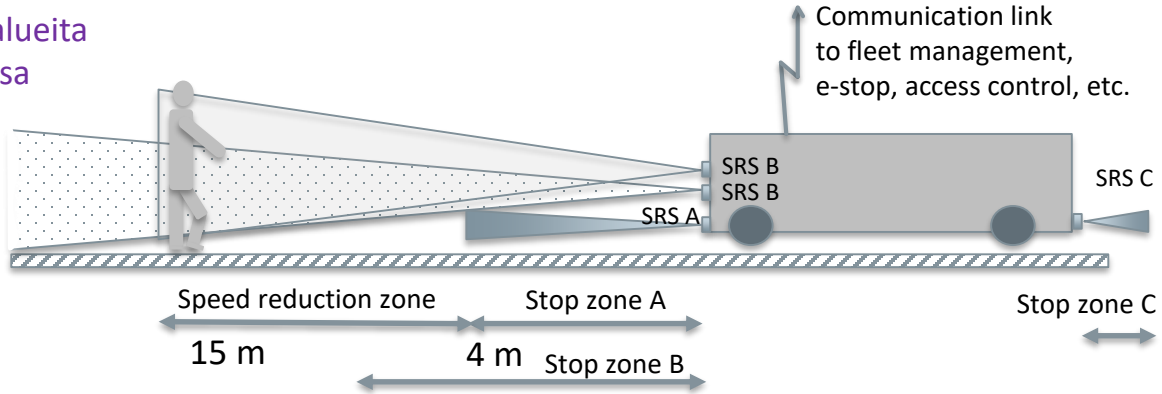
SRS A Safety laserscanner or radar; PL d (see Sick outdoorScan3; Inxpect LBK)

SRS B Safety laserscanner; PL c

SRS C Safety laserscanner or safety bumber; PL d

Speed reduction; combination of sensor information: lidar + radar

Antureilla erilaisia ja päällekkäisiä valvonta-alueita
Mikään anturi ei ole hyvä kaikissa olosuhteissa
PL d anturit:
määriteltyihin olosuhteisiin;
havaintoalue on rajallinen



Some pros and cons of object detection systems 5

Technology	Description	Advantages	Disadvantages	Range
Visual system and morpho-logical recognition	Visual system that uses camera and video analysis algorithms to detect obstacles and their classification according to their appearance.	Obstacle detection with the capability to differentiate pedestrians from hazards and objects to avoid unnecessary triggering of alarms. VA and ODS functionalities are integrated by design; easy installation. Detection zone can be precisely configured.	Cameras shall have direct visibility on the surveillance area. Might not detect a person with “unnatural appearance”, i.e. unusual posture or clothing, or incorrect angle from the system's cameras, making identification difficult. Above a certain level, dirt on lenses can lead to degraded detection/ recognition performances.	Maximum range from 6 m up to 15 m
Light Detection and Ranging (LIDAR)	An optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the object with pulsed light. It is a scanning laser rangefinder that generates a 3D point cloud of its environment. Similar to a radar in principle and operation but using laser light instead of radio waves, it is capable of detecting particles and varying physical conditions in the atmosphere.	Can be used close to or at some distance from the machine. No electronic emissions. Good field of detection.	Needs to be evaluated relative to heavy dust and heavy rain conditions.	Detection range is from 1,5 m (min.) to 120 m (max.) Vertical field of detection >20°, with most biased below the horizontal. Horizontal field of detection >250°

ISO 16001 esittelee n. 19 erilaista anturityyppiä ja niiden soveltuvuutta kohteiden havaitsemiseen työkoneympäristössä (maansiirtokoneet)

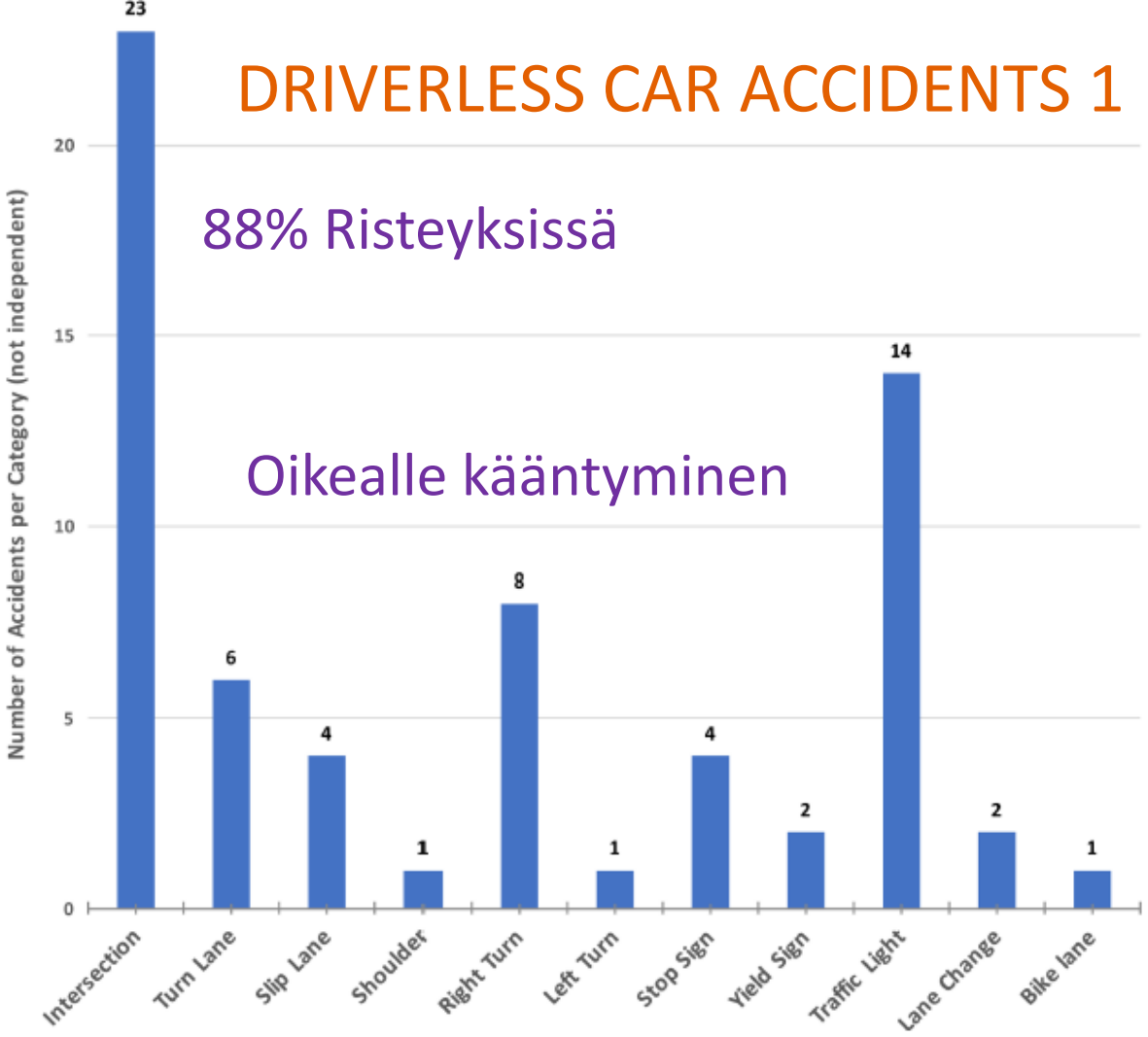
Ref: Earth-moving machinery. Object detection systems and visibility aids. Performance requirements and tests (ISO 16001:2017)

DRIVERLESS CAR ACCIDENTS 1

Specific characteristics and locations identified in the AV accident reports. Each column is out of 26 reports; categories are not mutually exclusive.

88% Risteyksissä

Oikealle kääntyminen

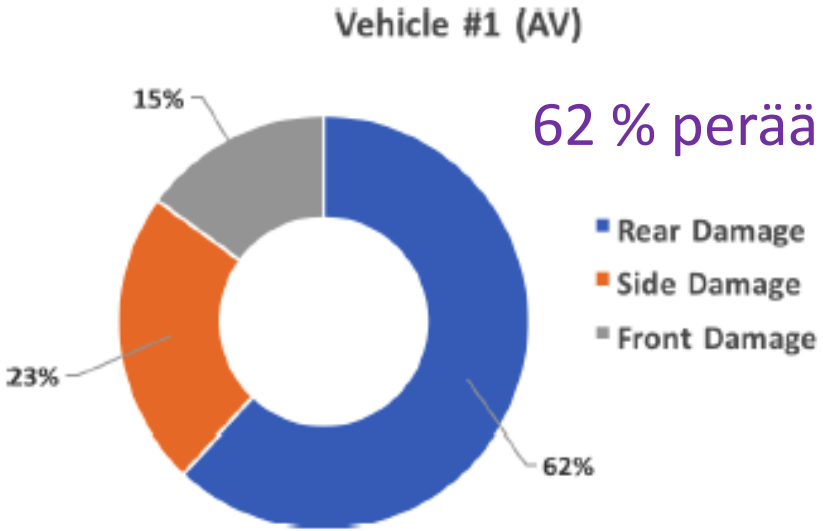


totally 26 accidents

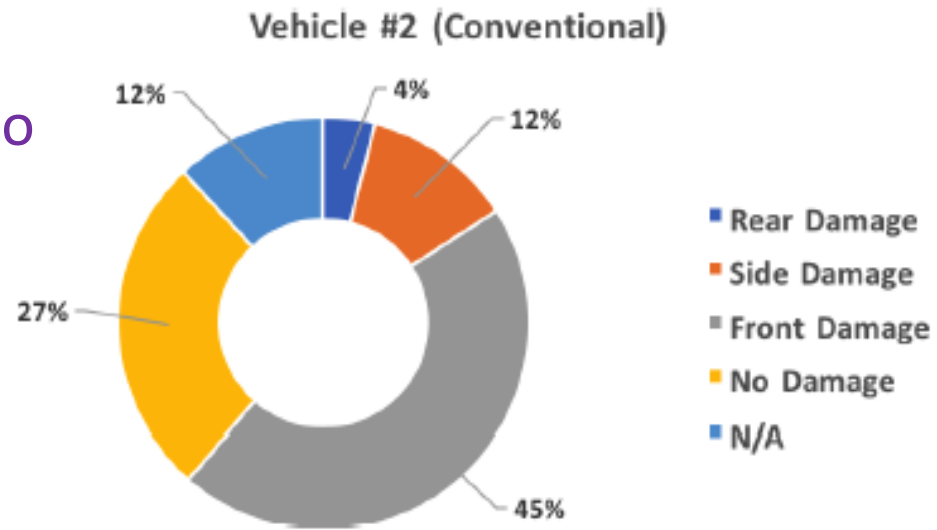
Favarò FM, Nader N, Eurich SO, Tripp M, Varadaraju N (2017) Examining accident reports involving autonomous vehicles in California. PLoS ONE 12(9): e0184952. https://doi.org/10.1371/journal.pone.0184952

DRIVERLESS CAR ACCIDENTS 2

Damage location breakdown for vehicles involved in collisions



62 % peräänajo



The average accident rate was 1 per 67000 km (usually lower, but getting better).
For conventional cars the value is 1 per 800000 km (narrow accident definition).

Kenen vika?

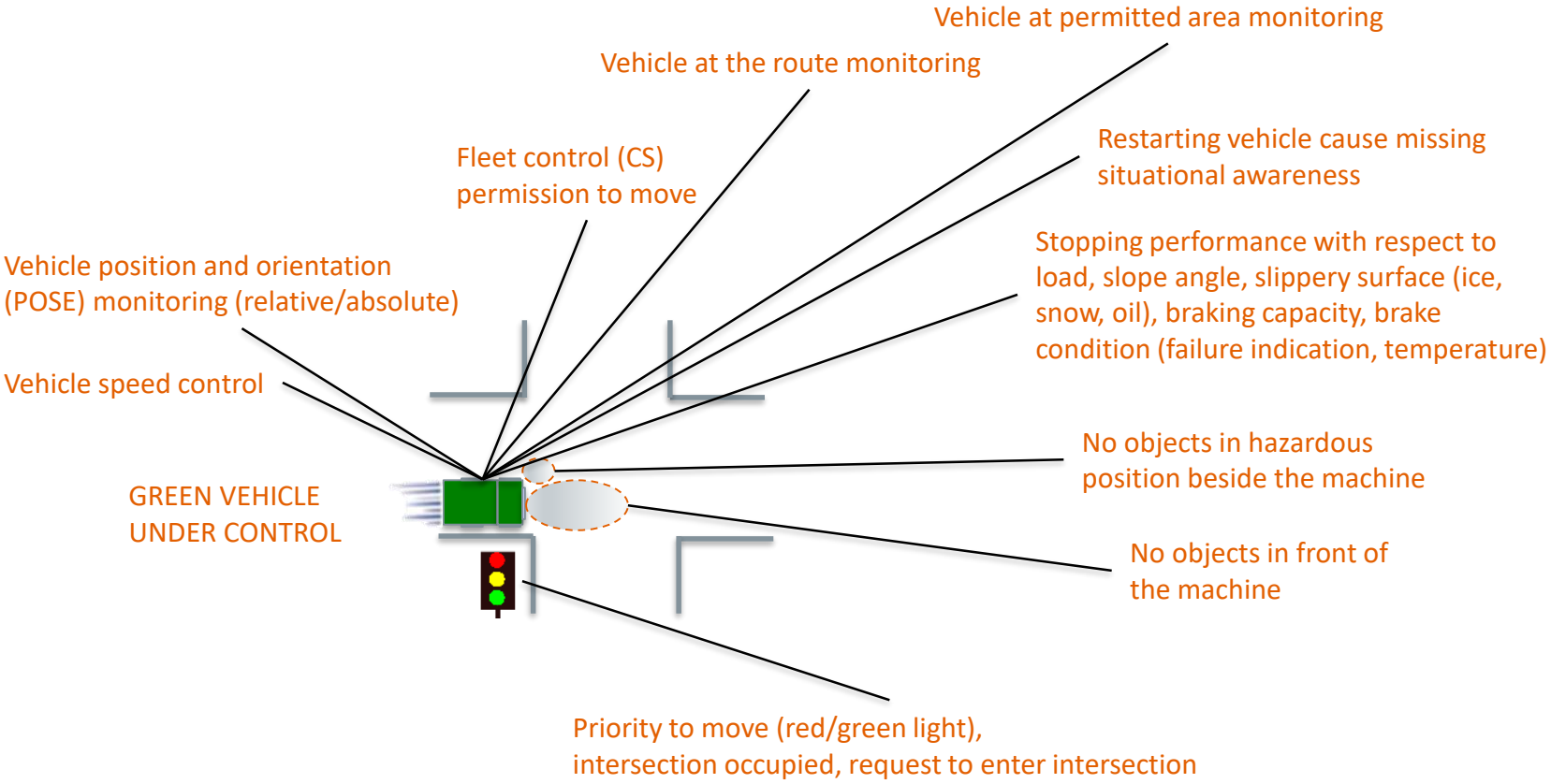
Favarò FM, Nader N, Eurich SO, Tripp M, Varadaraju N (2017) Examining accident reports involving autonomous vehicles in California. PLoS ONE 12(9): e0184952. https://doi.org/10.1371/journal.pone.0184952

Autonomous car fatalities

- 20 January 2016 Tesla, A Level 2 driving system expects a driver to be fully aware at any time of the driving and traffic situation and be able to take over any moment.
- 7 May 2016 Tesla
- 23 March 2018 Tesla
- 1 March 2019 Tesla
- 19 September 2019 Tesla
- In April 2019, the self-driving Tesla Model S caused a pedestrian fatality in Florida. (Miami Herald) This is one of the most disturbing Tesla autonomous vehicle accidents. The investigation is still ongoing, and it's not clear if the car was on Autopilot when the incident happened. The car entered a three-way stop sign intersection without stopping, hitting a parked pickup truck, which started spinning and then hit the woman.
- 18 March 2018 Uber A Level 3 autonomous driving system would occasionally expect a driver to take over control.

Kuolemantapauksia
Syyllisyyskysymys onnettomuuksissa

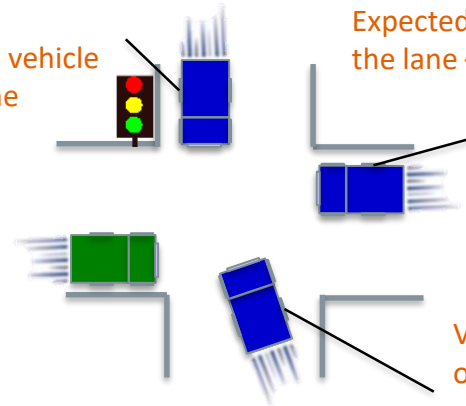
Intersection control risks – Vehicle



Ref: ISO 17757:2019. Earth-moving machinery and mining — Autonomous and semiautonomous machine system safety. 36 p.

Intersection control risks - Priorities

Vehicle need to be detected and priority for passing the crossing defined and acknowledged
- if the crossing is occupied the vehicle is not supposed to not enter the crossing



Expected to follow rules of the road and keep the lane – no oncoming collision expected

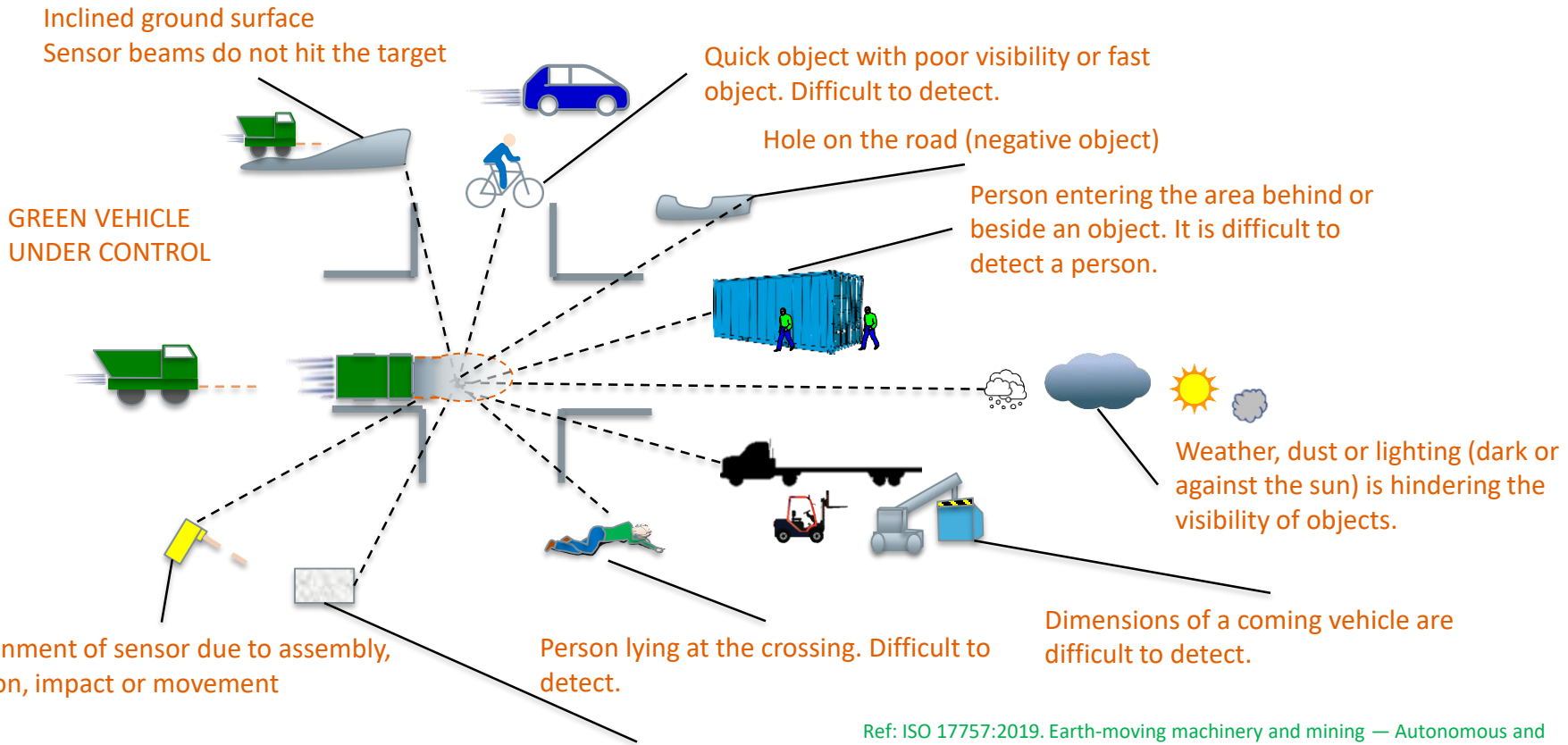
GREEN VEHICLE UNDER CONTROL

Vehicle need to be detected and collision avoided by stopping or reducing speed of the green vehicle
- The vehicle may enter the crossing if it is not occupied and it has priority acknowledged by other oncoming vehicles

Challenges:
- detect a standstill vehicle at about 9 m distance
- detect a vehicle behind corner
- detect all heights and widths of the vehicle and container
- detect changes, new objects in the environment

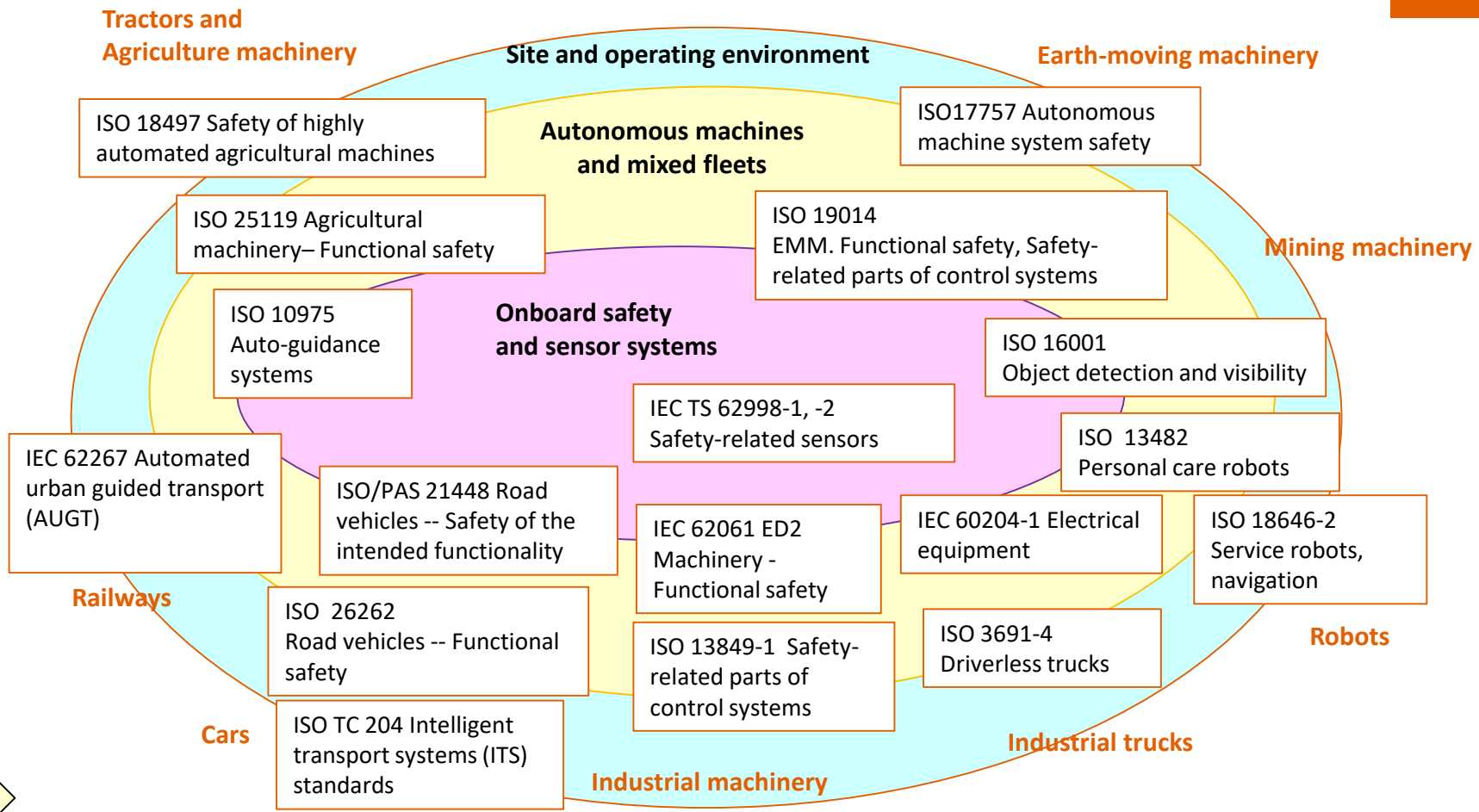
Possibilities:
- could the crossing be occupied for a specific vehicle by applying traffic lights, rules, central control

Intersection control risks - Perception



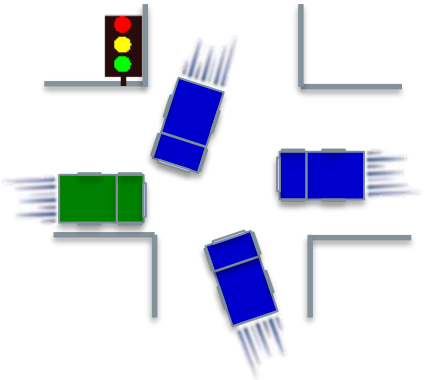
Ref: ISO 17757:2019. Earth-moving machinery and mining — Autonomous and semiautonomous machine system safety. 36 p.
ISO 16001:2017. Earth-moving machinery. Object detection systems and visibility aids. Performance requirements and tests. 79 p

Safety standards related to autonomous machinery



Notes

GREEN VEHICLE
UNDER CONTROL



If traffic rules are not obeyed, it is not possible to avoid collisions, since there is so little time to react.

Challenges:

- detect a standstill vehicle at about 9 m distance
- detect a vehicle behind corner
- detect all heights and widths of the vehicle and container
- detect changes, new objects in the environment

Collisional hazard levels in phases

Means to minimize damages

Means to avoid collision

Means to control sound maneuvers

Collision hazard phase
The movement is bound to cause collision.

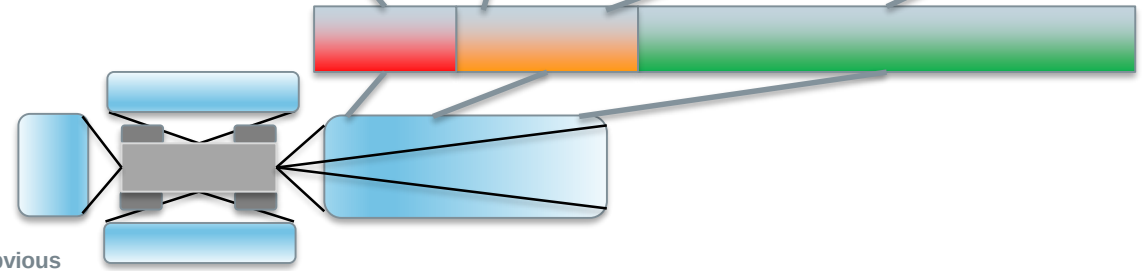
Could bumpers ease collision consquences enough?

Proximity phase
Objects are in the proximity of machine moving path and potential collision is predicted.

Risk of collision is high, but not unavoidable.

Time or distance to the predicted collision point is relatively long.

Normal phase
No hazardous object in the proximity of machine moving path



Ref: ISO/WD 21815-1. Earth-moving machinery -- Collision awareness and avoidance -- Part 1: Performance requirements and tests.

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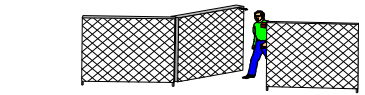
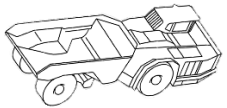
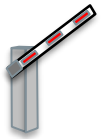
2. Access control and isolated area for autonomous machines
- Entering restricted area stops the autonomous machines

Typical safety capability
High

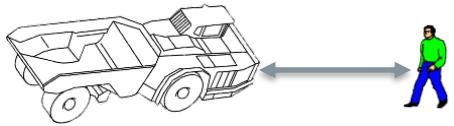
Low



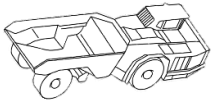




Isolation and separation capabilities are applied.



Rules for automated area and area isolation are applied



3. Safe separation distance between machines and humans
- Objects are tracked or detected in front of the mobile machine.

Rules for automated area and separation distance.

1. Rules for automated area
- Typical for manual systems e.g. traffic

Thank you for your attention!

Questions?

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