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Crossing a public road with heavy Automated Guided Vehicles (AGV)

Closing the regulatory gap between AFGBV and exemption from registration for vehicles with maximum design speed of up to 6 km/h

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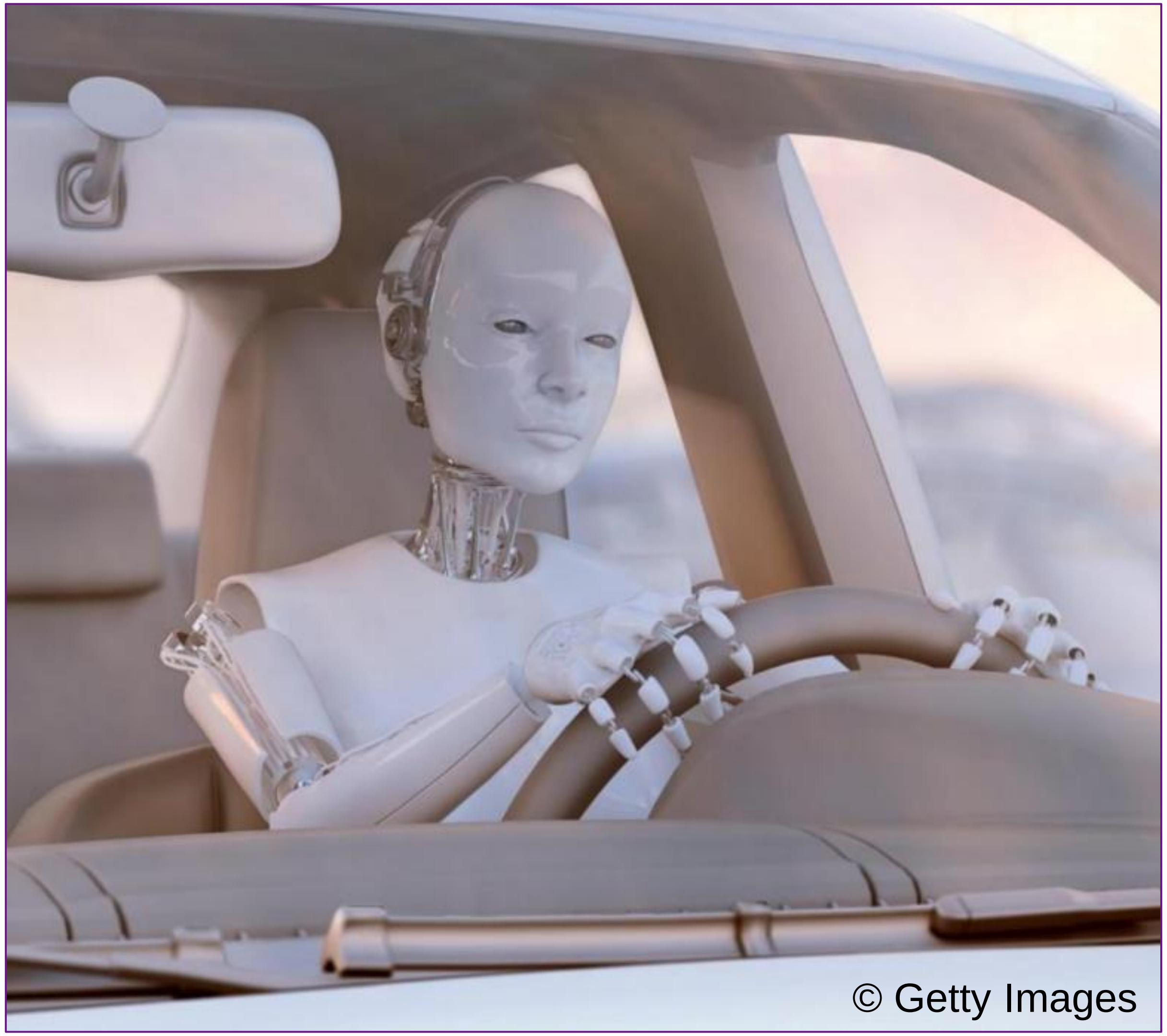
Content



- **Introduction**
- Road Safety
- Functional Safety
- Resume and outlook

Use Case

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- Crossing a public road with Automated Guided Vehicles (AGVs), made for internal transport, with maximum design speed of up to 6 km/h and 30 tones gross weight

- Complexity of operational domain is low and operation may be restricted, e.g., in extreme weather & visibility conditions, major operations by fire brigade or ambulance service in immediate vicinity

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- Not subject of consideration: Activities on company ground (loading and un-loading, driverless operation, charging traction batteries etc.)

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Environmental perception of AGVs

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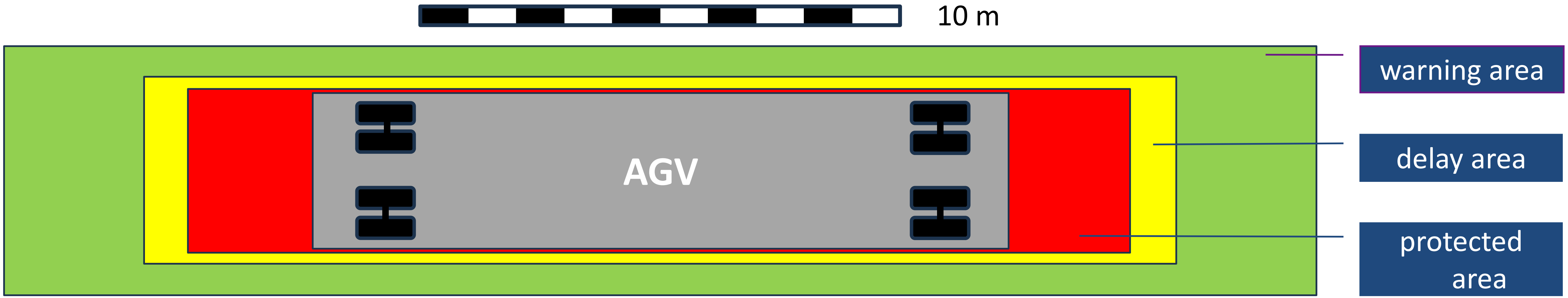

- AGVs are capable of detecting people and objects ahead of and in their immediate vicinity and stop appropriate (safety areas - as typically guaranteed by manufacturers - regardless of actual sensor coverage)
- AGVs are not capable of detecting crossing road users approaching at relatively high speed in appropriate time
- **Solution: Combination of AGV with smart Traffic Light Systems (TLS)**

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Technical concept

Blue boxes: parts of smart TLS
Green boxes: Company responsibility

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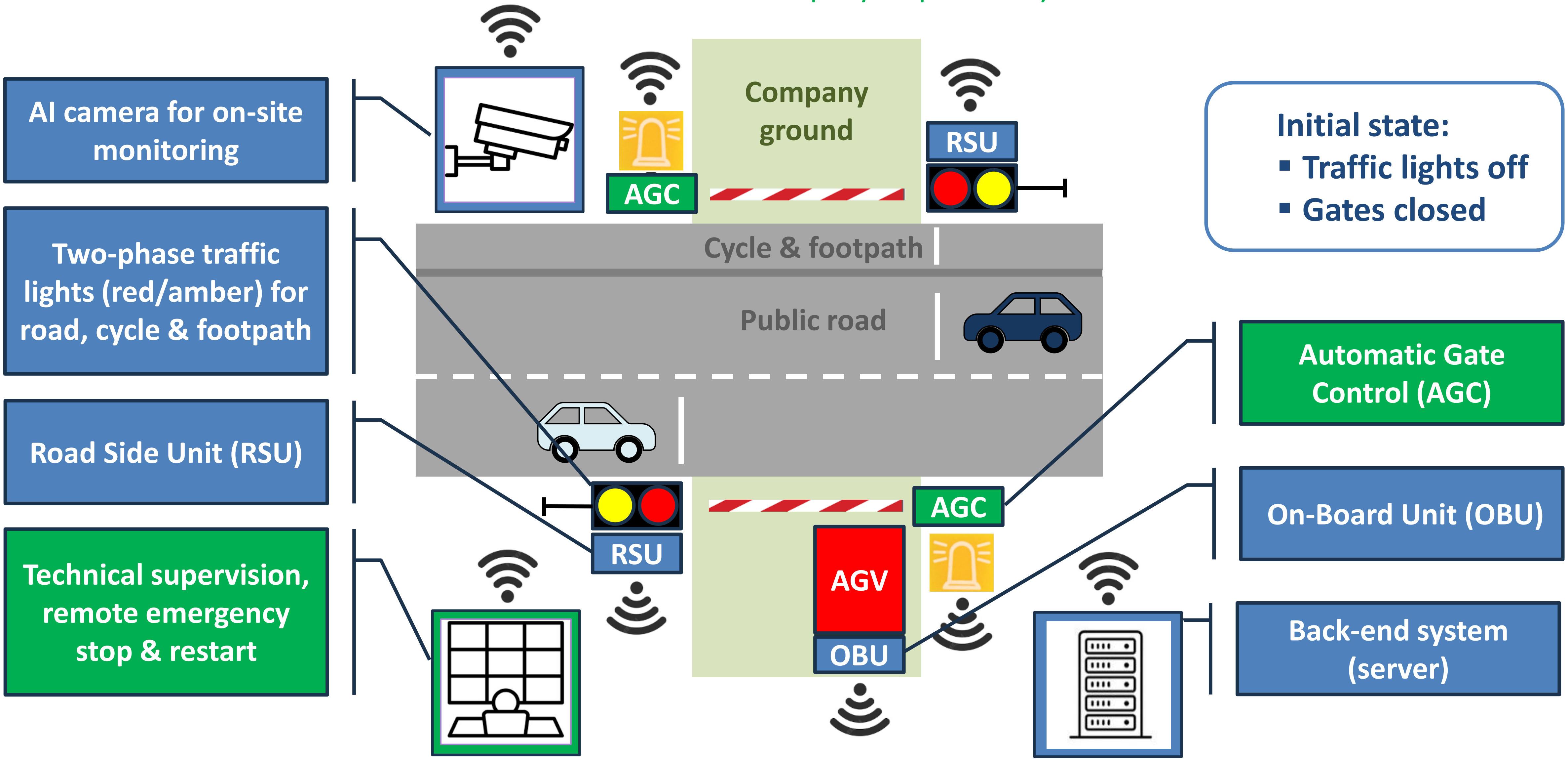

Initial state:
- Traffic lights off
- Gates closed

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Project phases

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- <u>Phase 1, scheduled for mid-2026:</u>
  Manual operation of AGVs on public road w/wo TLS, operator with control panel on site

- <u>Phase 2, scheduled late 2026 - early 2027:</u>
  Commissioning of AGVs in combination with TLS, supervisor with emergency stop button on site

- <u>Phase 3, scheduled for spring 2027:</u>
  Regular driverless operation of AGVs with TLS and remote technical supervision

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Legal and normative framework

- <u>Road vehicle permit ➔ Road safety</u>
  - Compliance of AGVs with applicable construction and operating regulations for road vehicles (including non-functional safety requirements like EMC, HV safety) or, respectively, argumentation for necessary exceptions to these regulations
  - Result: Vehicle approval & registration (also relevant for safety case)

- <u>Product safety & liability ➔ Functional safety</u>
  - Compliance of E/E systems - including interaction between these systems - with functional safety requirements following ISO 26262 🚗 / IEC 61508 🏭 / ISO 13849 🏭 and cyber-security following ISO/SAE 21434 🚗 / IEC 62443 🏭
  - Result: Safety case & hazard invalidation (also relevant for vehicle approval)

🚗 ... Automotive standards 🏭 ... Industrial standards

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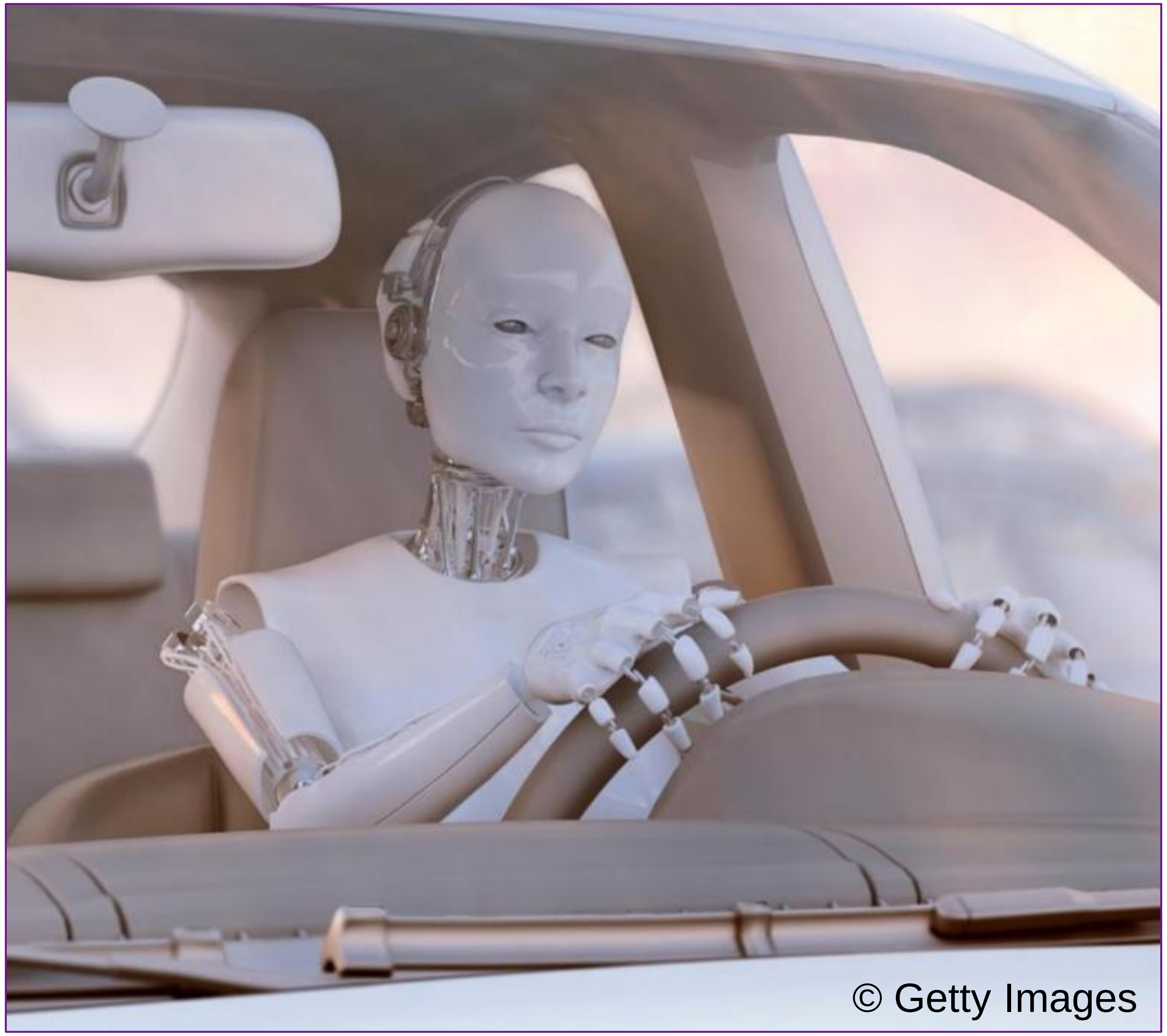

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Approval

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Overall objective: Not to harm anyone or endanger, obstruct or disturb anyone more than unavoidable according to §30(1) StVZO

(1) Exemption from operating license & registration for vehicles with maximum design speed up to 6 km/h acc. to §1(1) FZV *not applicable* because

- driverless vehicles are not foreseen in this regulation
- AGVs do not comply with construction and operating regulations for road vehicles, exceptions are required

(2) Operating license by KBA acc. to national regulation for autonomous driving within specified operating areas (AFGBV) *not applicable* or, respectively, cannot be fulfilled

Solution: Application of single approval acc. to §21 StVZO in conjunction with §70 StVZO at competent authority under state law

Conclusion: Although use case appears very straightforward and various regulations seem to apply, obtaining permit is complicated!

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Road safety requirements

- Braking system
  - Redundant service brake with a minimum deceleration of 3.5m/s²
  - Parking brake with a minimum deceleration of 1.5m/s²
- Steering – ensuring safe lane tracking
- EMC – compliance with limit values for electromagnetic emissions and immunity
- HV safety, if applicable
- …

- Lighting, amongst others,
  - front: low beam, parking lights
  - rear: tail lights, rear reflectors
  - side: side marker lights, side reflectors
- Direction indicators including hazard warning lights
- Rotating beacons
- …

Deviations, solutions and procedure

- Deviations from construction and operating regulations for road vehicles that requires exceptions
  - Axle load and vehicle dimensions → structural upgrading and restriction of use to specified road section
  - Absence of conventional controls for longitudinal and lateral movement → safety case and hazard invalidation
- Approval measures for different project phases
  - Manual operation with operator on site → same procedure like, e.g., for exceptional authorization for forklift trucks
  - Commissioning & regular operation → expanded exceptions
- Consultation with the relevant authorities according to regulation → registration office, district and regional authorities, possibly relevant state ministries

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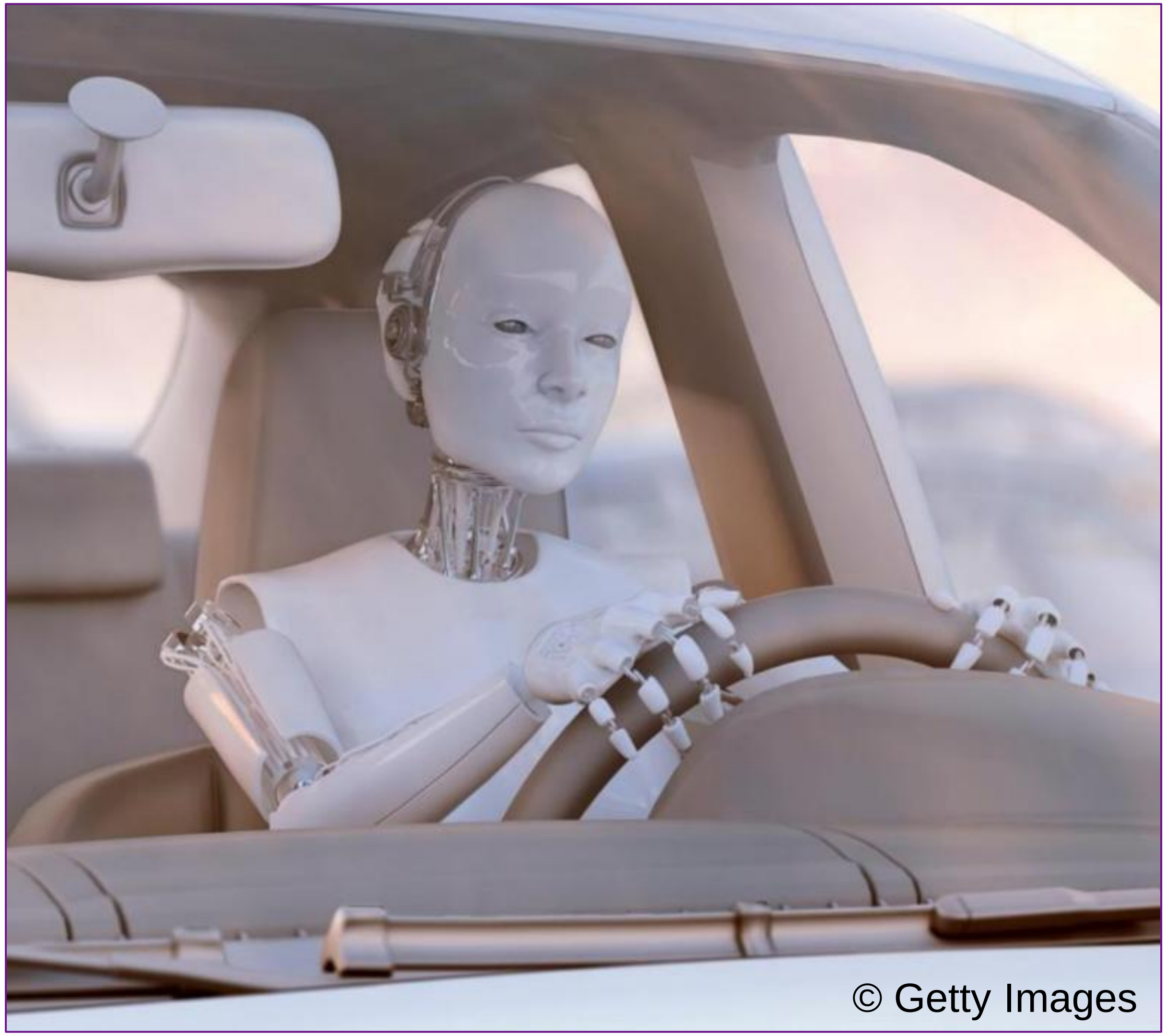
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Safety case

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- Basic: Available certificates for safety & security of AGVs and TLS, including RSU, OBU, communication and back-end system
- Definition of use case specific intended functions for entire system, including
  - intended use (crossing public road)
  - technical supervision, remote emergency stop & restart
  - recovery measures
- Hazard Analysis and Risk Assessment for use case specific intended functions → Functional Safety Requirements (FSR)

Simplified flowchart

Initial state: TLS off, gates closed

↓

Arriving AGV requests TLS on, gate opening and stops at gate if necessary

↓

TLS switches to yellow / red and gates open

↓

AGV starts to cross when gates are open and TLS is red

↓

Departing AGV requests TLS off and gate closing

↓

Finals state: TLS off, gates closed

Basic requirements

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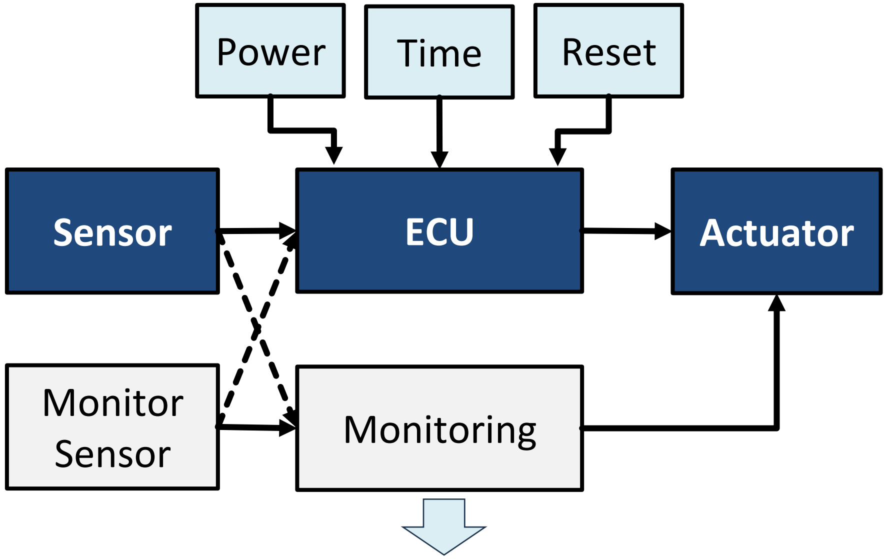
Fail-safe design

- Systems detect faults and shut down in case of fault (i.e., they either perform intended function or do nothing at all)
  - False positive: Avoiding / detecting wrong actions or signals – shut down
  - False negative: No action – no risk (for example no emergency power supply necessary for safety reasons)
- Resulting HW architecture complex
- Prerequisite: Shut down in case of a fault provides safe state (emergency stop)!



Example for fail-safe HW architecture

→ Core system: Sensor – ECU – Actuator

→ Intended function controlled by several monitor units (e.g., for power and time) and by a separate monitoring channel

→ Once fault has been resolved, function is available again after reset

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Safety mechanisms & fallback measures

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Technical measures

- Vulnerable road users are suitable protected by AGV’s safety system
- Monitoring, emergency stop and restart capability by technical supervision
- All E/E systems are fail-safe, certified and proven in use - Proof of sufficient safety during test and commissioning

Operational & organizational measures

- Recovery measures, e.g. securing and towing AGV broken-down on public road
- On-site information by signs
- Information to “blue light community” (to equip all emergency vehicles in the region with OBUs is possible but not propriate)

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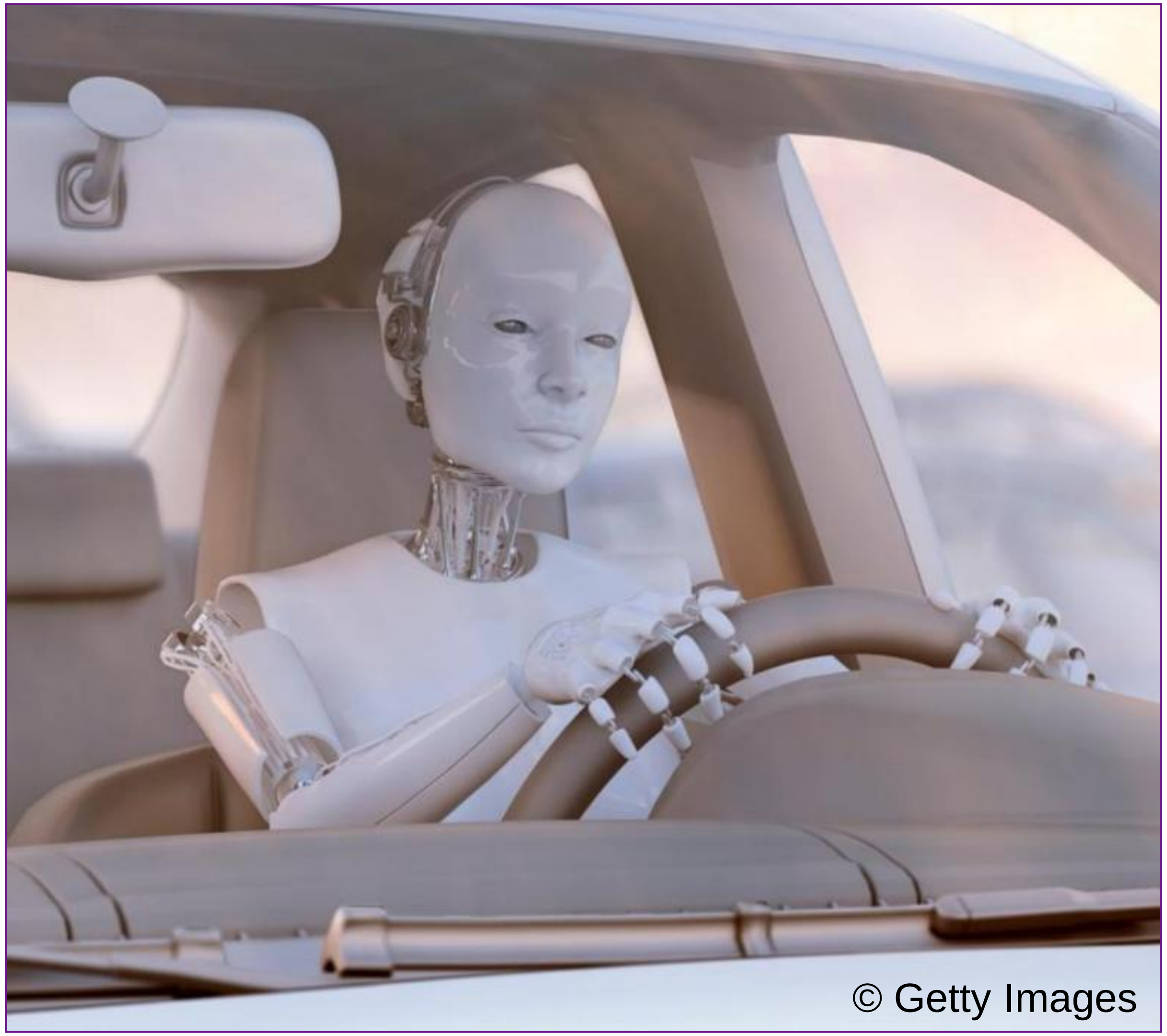

Resume

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- Use case: crossing a public road with AGVs, designed for internal transportation, combined with smart TLS

- Although operational domain is not very complex and several potential regulations are available, obtaining approval is not simple
  - Neither AFGBV nor exemption from registration for vehicles with maximum design speed of up to 6 km/h help
  - Solution: Single approval acc. to §21 StVZO in conjunction with §70 StVZO

- Exceptions are necessary caused by deviations from construction and operating regulations for road vehicles (axle load, dimensions etc.)

- Close coordination with relevant authorities necessary regarding procedure

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Resume

- All E/E systems are fail-safe designed, certified and proven in use

- Safety case focused on verification of
  - ➢ new implemented functions, e.g., technical supervision
  - ➢ use case specific interaction between these systems

  and implementation of supplemented operational and organizational measures, e.g., towing broken-down AGVs or dealing with emergency vehicles

- Sufficient safety will be proofed during test and commissioning phase

Outlook

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- Use case is very common across industries
- In less complex operational domains, combination of AGVs and smart TLS is ideal solution to save staff and costs (Level 4 trucks too expensive and not necessary)
- Easy to scale because all components are available - AGV and TLS suppliers seem very interested
- Process reliability for authorization currently not guaranteed → solution
  - Initially, stakeholders can jointly conduct pilot procedures based on exemptions and draw up something like guidelines for reliable practical implementation
  - In principle, regulation should be further developed to enable regular authorization of AGVs and smart TLS in less complex operational domains

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Thank you for your time.
Are there any questions?

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