

Safely designing mobile robots

Ready for the future – design of safe mobile robots



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Introduction

Ensuring safety for the collaboration of people and AGV systems

When people, mobile robots (AMRs) and automated guided vehicles (AGVs) work in the same area, special safety requirements arise. People do not consciously enter a hazardous area, but rather find themselves in the path of a hazardous area due to the use of AGVs and AMRs – possibly without even realizing it. In order to protect people from injuries, the Machinery Directive 2006/42 / EC stipulates that machines may only be brought into the European market in a manner that ensures safety.

This e-guide provides an overview of the current requirements and provides practical advice on the safe design and implementation of mobile robots and automated guided vehicle systems.



Legal framework

New requirements and standards for machine safety beginning 2027

Up until 19 January 2027, the Machinery Directive will continue to create the legal framework for machine safety on the part of the machine manufacturer. From 20 January 2027 onwards, the declaration of conformity must be made in accordance with the new EU Machinery Regulation (EU) 2023/1230.

Harmonized standards suggest solutions for the legally compliant implementation of requirements. Although application of these solutions is voluntary, it results in a presumption of conformity. Harmonized standards are published in the Official Journal of the EU and are relevant for the design of safe mobile robots.



Standards and regulations for safe mobile robots

Overview of the most important safety standards

The most important standards for AGVs and mobile robots:

- **EN ISO 12100:2010-11:** Safety of machinery – General design principles – Risk assessment and risk reduction
- **EN ISO 13849-1:2023-05:** Safety of machinery – Safety-related parts of control systems
- **EN ISO 3691-4:2023-07:** Industrial trucks – Safety requirements and verification

If there is a C standard for the machine under consideration (in this case EN ISO 3691-4), preference should be given to this standard.

Further information on the topic of machine safety can be obtained by manufacturers, designers and distributors in the “[Guide for Safe Machinery](#)”.

Other important standards and regulations related to the development of safe mobile robots:

- EN 1175:2020-07 Safety of industrial trucks – Electrical/electronic requirements
- VDI 2510 Sheet 2:2022-12 Automated guided vehicle systems (ATVs) – Safety of ATVs
- EN ISO 13854:2019-09 Safety of machinery – Minimum distances to avoid crushing of body parts
- EN IEC 62046:2018-07 Safety of machinery – Use of protective equipment to detect the presence of persons (IEC 62046:2018).



Risk assessment for mobile robots and AGVs

Legal requirements and practical implementation

The **Machinery Directive 2006/42 / EC** – implemented in Germany in the ninth ordinance of the Product Safety Act – describes the legal requirements for the safety of machines and systems. Appendix 1 lists the essential health and safety requirements. The general rule is that a risk assessment must be carried out to determine the safety and health protection requirements that apply to the machine.

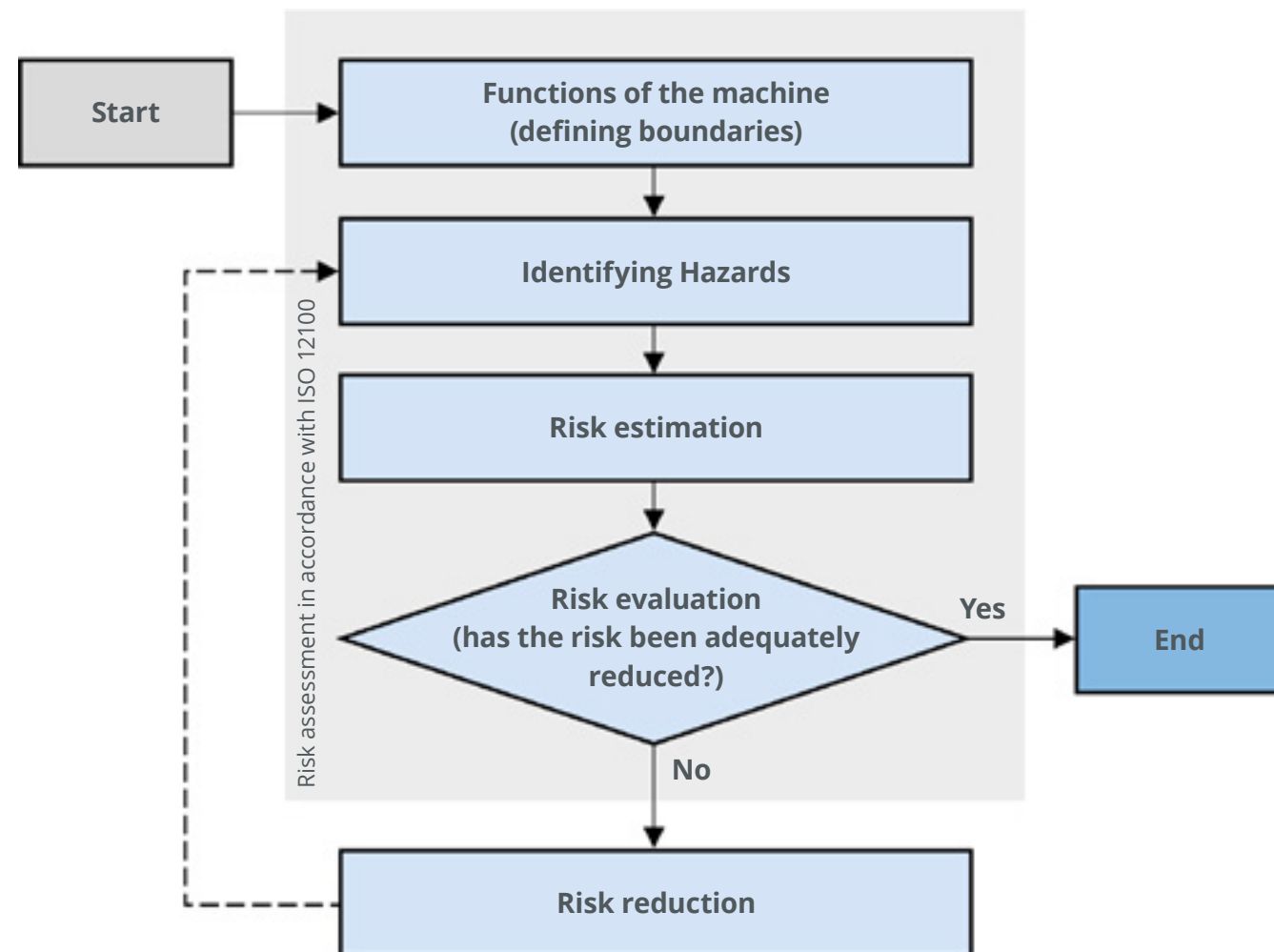
Risk assessment and risk reduction



Risk assessment and risk reduction

A comprehensive risk assessment is always crucial for the development of safe mobile robots, AGVs, AMRs and AGV systems..

The process of risk assessment



The process includes identifying, analyzing and mitigating risks. Essential steps include:

- **Identification of hazards:** Analysis of the work environment and tasks.
- **Risk estimation:** Severity of injury + probability of occurrence.
- **Risk evaluation:** Is the risk acceptable or not?
- **Risk reduction:** Implementation of suitable safety measures.
- **Documentation of the process and results.**

To determine the PL_r (Performance Level* required), EN ISO 3691-4 is used first. This specifies in detail the risks¹ relevant to an AGV, e.g.:

- Through moving parts: crushing, impact, shearing
- By the approach of a moving element to a fixed part: crushing, impact
- From falling objects: crushing, impact
- Due to gravity or stability: crushing

and indicates² the PL_r for the resulting safety functions. Alternatively, there is the option to work with the diagram for determining the PL_r from EN ISO 13849-1³.

PL_r are the basis for risk reduction and can be ascertained using the diagram for determining the PL_r from EN ISO 13849-1.

Risk assessment and risk reduction

These hazards affect people who may be on the route or at transfer points.

The hazards come from the vehicle, the load and the environment.

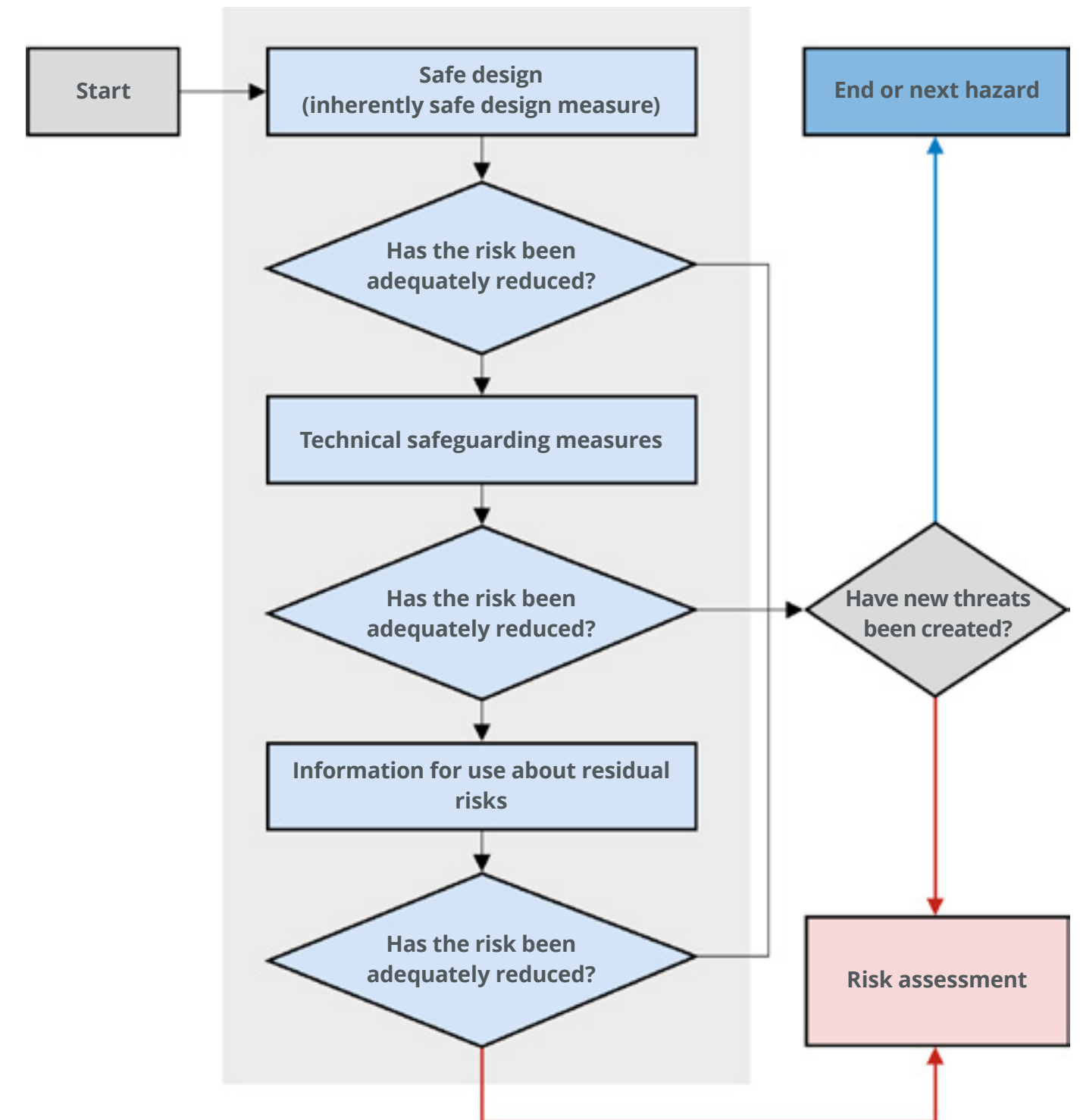
Individual technological solutions and safety functions are therefore required for safe operation. According to the Machinery Directive, risk reduction measures must be implemented using the

“3-step method”.

- **1. Safe design**
- **2. Selection of safeguarding measures**
- **3. Information, training, and personal protective equipment**

It is always advisable to ensure from the very outset that the design work prevents the occurrence of hazards. Only after this step should the technical safeguarding measures be selected. Lastly, information must be provided in the form of operating instructions, warning signs, organizational measures or instructions on the use of personal protective equipment.

The steps “Assess risk” and “Mitigate risk” must be repeated until the residual risk is acceptable.



Technologies and approaches for risk reduction

Effective and integrated safety concepts

With the increasing automation and integration of advanced AGV systems, effective safety concepts must be developed. Safety and risk reduction are central aspects when it comes to safeguarding people and machines. This section highlights technologies and approaches for risk reduction based on a careful risk assessment.

Protective devices
Safety functions
Technological solutions for risk reduction
Safeguarding the route of mobile robots
Person detection test
Challenges for mobile robots and AGVs



Protective devices

The risk assessment determined the required PL_r, which forms the basis for the safety level of the protective function and applies to all the subsystems (components) involved. A technological safety concept for the safety functions must now be developed.

The following aspects must be taken into account:

- Features of the machine, such as the ability to stop the vehicle at any time or adjust the braking distance.
- Features of the environment, such as ambient light or noise, reflective surfaces, contamination or fog and weather conditions.
- Application-specific properties, such as mixed operation (people on the route), condition of the route (width, crossovers, block storage).
- Reasonably foreseeable misuse, e.g. riding along.

A technical safety measure is implemented using one or more safety functions that consist of at least one protective device.

There are three types of protective devices:

1. Mechanical protective devices that separate people from parts, substances or radiation or permanently prevent access (e.g. foot protection).⁶
2. Protective devices that are integrated into the controller of the machine to initiate a safe status as soon as people or parts of the human body are detected.
3. Protective devices that are integrated into the controller of the machine to initiate a safe status as soon as the monitored safety-related limits of machine parameters (position, speed, force, etc.) are exceeded.

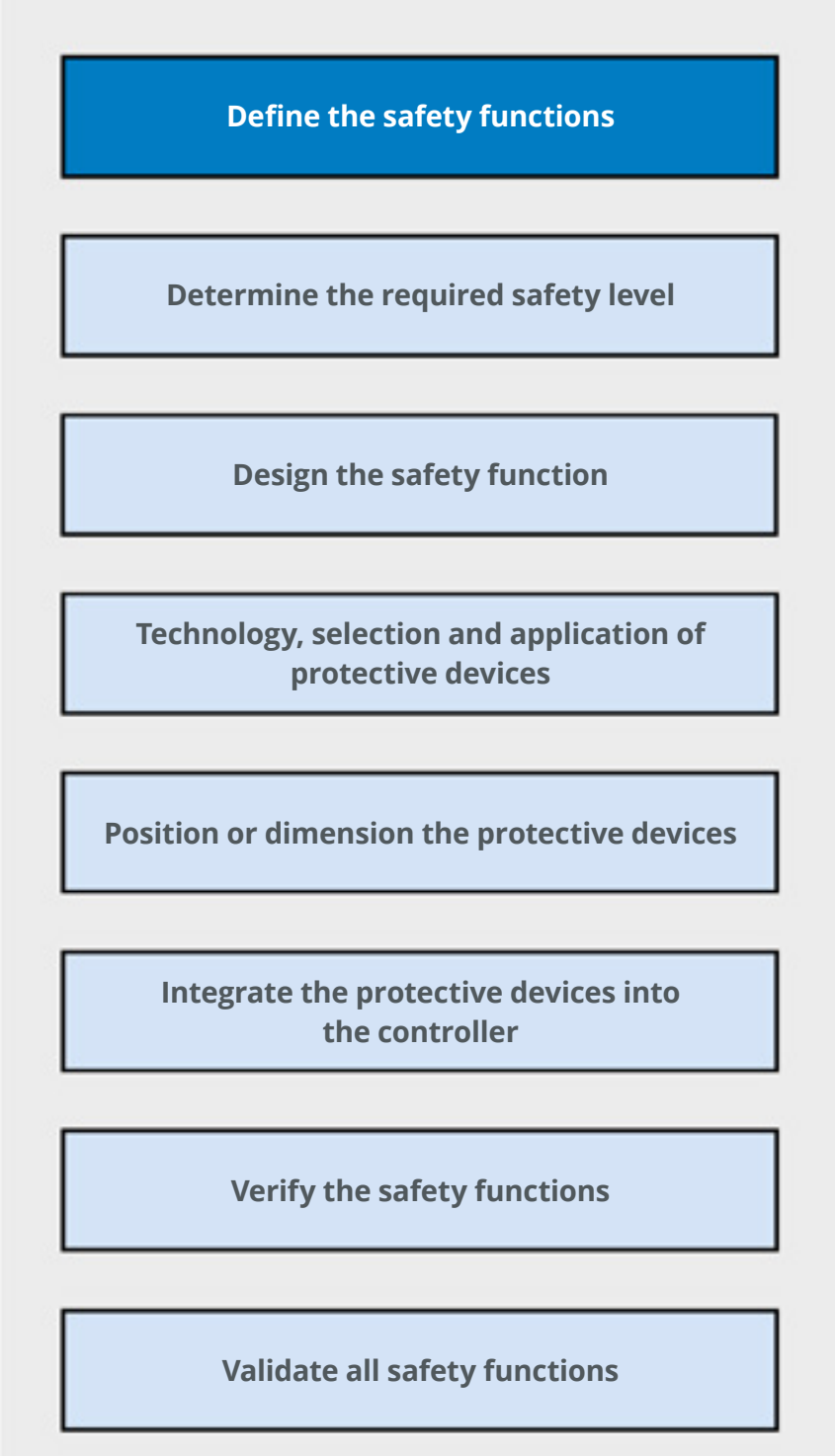
All of these protective devices implement safety functions, although not every protective device has to be integrated into the machine controller. Fixed physical guards, such as fences, barriers and covers, are, for example, not integrated, but if designed correctly they can meet the requirements of the safety function. If protective devices are integrated, risk reduction depends on the correct functioning of the controller, which is referred to as functional safety (see EN ISO 13849-1). The requirements of the respective protective measure must be implemented with suitable components. When using safety components from well-known manufacturers, the necessary information, such as the performance level of a safety laser scanner, is available.

Safety functions

Possible safety functions for mobile robots and AGVs⁷:

- Initiate a stop – e.g. when a person approaches an AGV.
- Avoid unexpected restart – after triggering the “Initiate a stop” function or switching on the machine, actions should be consciously taken to start the machine.
- Prevent restart – if a person is in the hazardous area, the machine is prevented from restarting.
- Combination: Initiate a stop and prevent a restart – as soon as a person steps into the hazardous area, a stop is initiated and restart is prevented for as long as the person remains there.
- Enable material passage (differentiation between man and material) – when entering or leaving a hazardous area, the AGV does not trigger any protective device, but a person will be detected.
- Monitor machine parameters (e.g. speed or position).
- Basic protection of shared work spaces for people and machines (e.g. load transfer areas).⁸

To reduce risk, the necessary safety functions are defined. Information about the safety functions can be found in EN ISO 3691-4.⁴ It should be possible to manually cancel safety functions for a limited period of time for safe commissioning or maintenance. This muting is also used in certain work areas, including in tight spaces. In this case, there must be an alternative safety function such as reduced speed or a manually operated stop function to ensure safety. As a further measure, according to EN ISO 3691-4, an emergency stop according to ISO 13850:2015 ⁵ must be implemented.



Technological solutions for risk reduction

Modern technologies are central to risk reduction. For AGVs and mobile robots, SICK offers a range of products including the following:

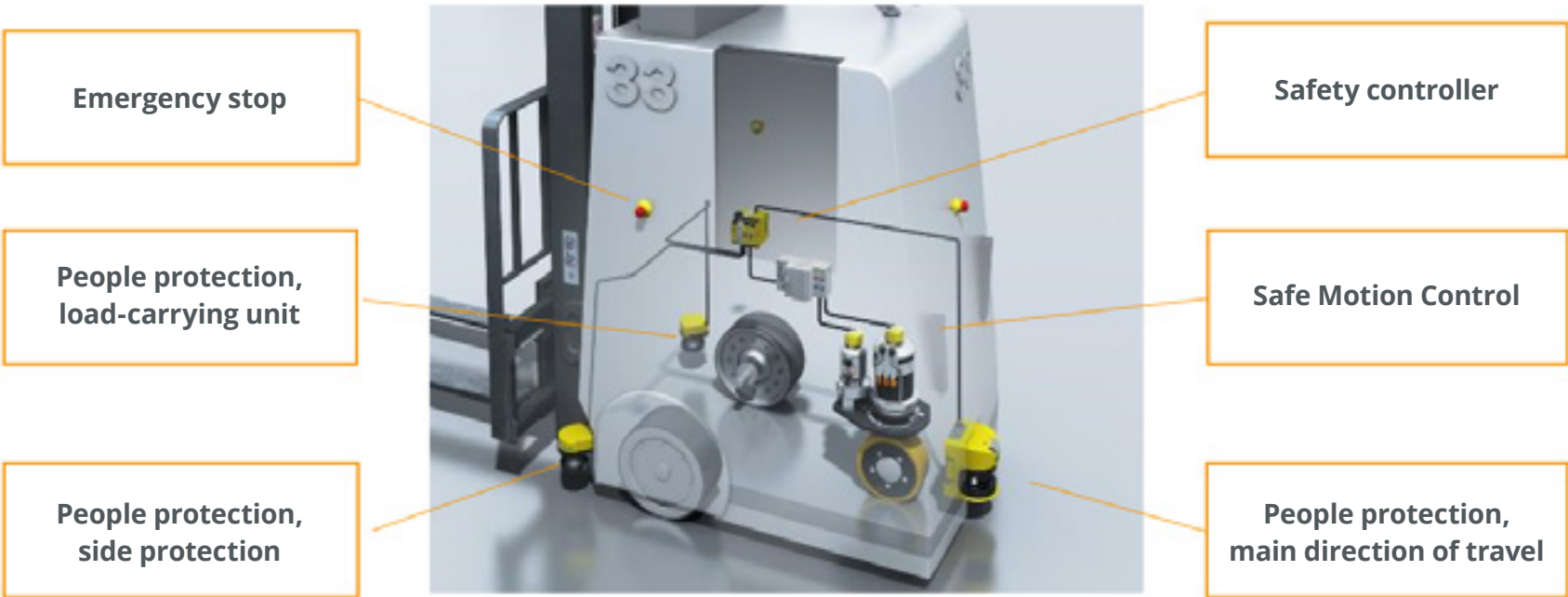
- Safe 3D cameras and safety laser scanners such as [safeVisionary2](#), [microScan3](#) and [nanoScan3](#).
- Modern controllers for dynamic adjustment of detection areas depending on the driving situation and ambient conditions..

With [scanGrid2](#), SICK provides a cost-effective safety solution for side protection of vehicles or route protection for small, line-guided AGVs.

The safety laser scanners use a horizontal protective field to create a virtual protection area in which objects and people are detected and thus protected. In addition, the measurement data can be used to localize the mobile robot.

Important safety components in an AGV

In accordance with ISO 3691-4 or ISO 13849, different performance levels must be taken into account



Safeguarding the route of mobile robots

Safeguarding the route is an important criterion for the safe operation of automated guided vehicle systems. EN ISO 3691-4 defines the different work areas in which the vehicle moves:⁹

- **Area of operation:** An area open to all people without specific training, instruction or knowledge. In this area, people detection in the direction of travel must be active. A minimum clearance of 0.5 m wide and 2.1 m high must be ensured along the route between continuous, solid, closed structures (e.g. walls) and between vehicles.
- **Operating hazard area:** An area in which an industrial truck is in operation. Here, too, people detection must be active in the direction of travel. If there is a free space of 0.5 m wide and 2.1 m high between the vehicles along the route and less than 0.1 m from continuous, solid, closed structures (e.g. walls), the maximum permitted speed is the same as the rated speed of the vehicles.
- **Restricted area:** A physically separated area (partition at least 2.1 m high) which only authorized persons have access to (e.g. block storage or narrow aisles). As there is no escape route, an accessible, manually operated stop function must be available on all sides of the vehicle within a radius of 600 mm from the hazardous point. A virtual bumper can be used as a stopping device. The maximum speed in this area is 0.3 m/s.
- **Closed area:** An industrial truck operating area in which risk reduction is implemented via structural separation.



Person detection test

With mobile hazardous area protection, the approach of a person to a vehicle and the presence of a person in the hazardous area should be detected. The people detected have to be standing – with the exception of those who step sideways into the path or walk towards the vehicle.¹⁰ This requires detection of the lower limbs. If necessary, the application may require that people lying down be detected.

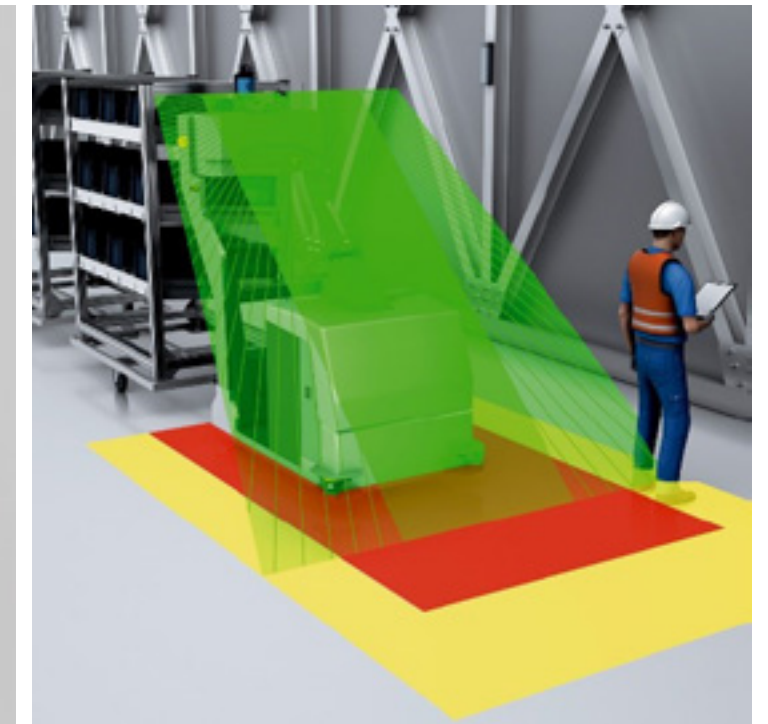
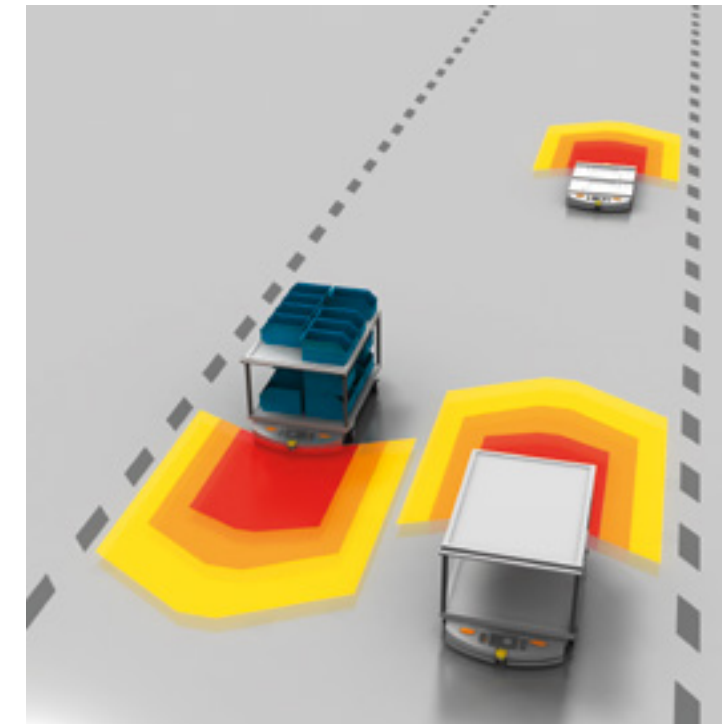
When designing the protective field, allowances for measurement errors, lack of ground clearance, retro-reflectors in the scan plane and decreasing braking force must be taken into account. To validate the protective function, person detection tests¹¹ are required:

Person lying down:

- Test body: Ø 200 mm and L 600 mm
- Horizontal on the ground and vertical to the direction of travel
- Repeat test with test body at positions left, middle, and right

Person standing up:

- Test body: Ø 70 mm and L 400 mm
- Vertical on the ground and perpendicular to the direction of travel
- Retest with test body at positions left, middle, and right

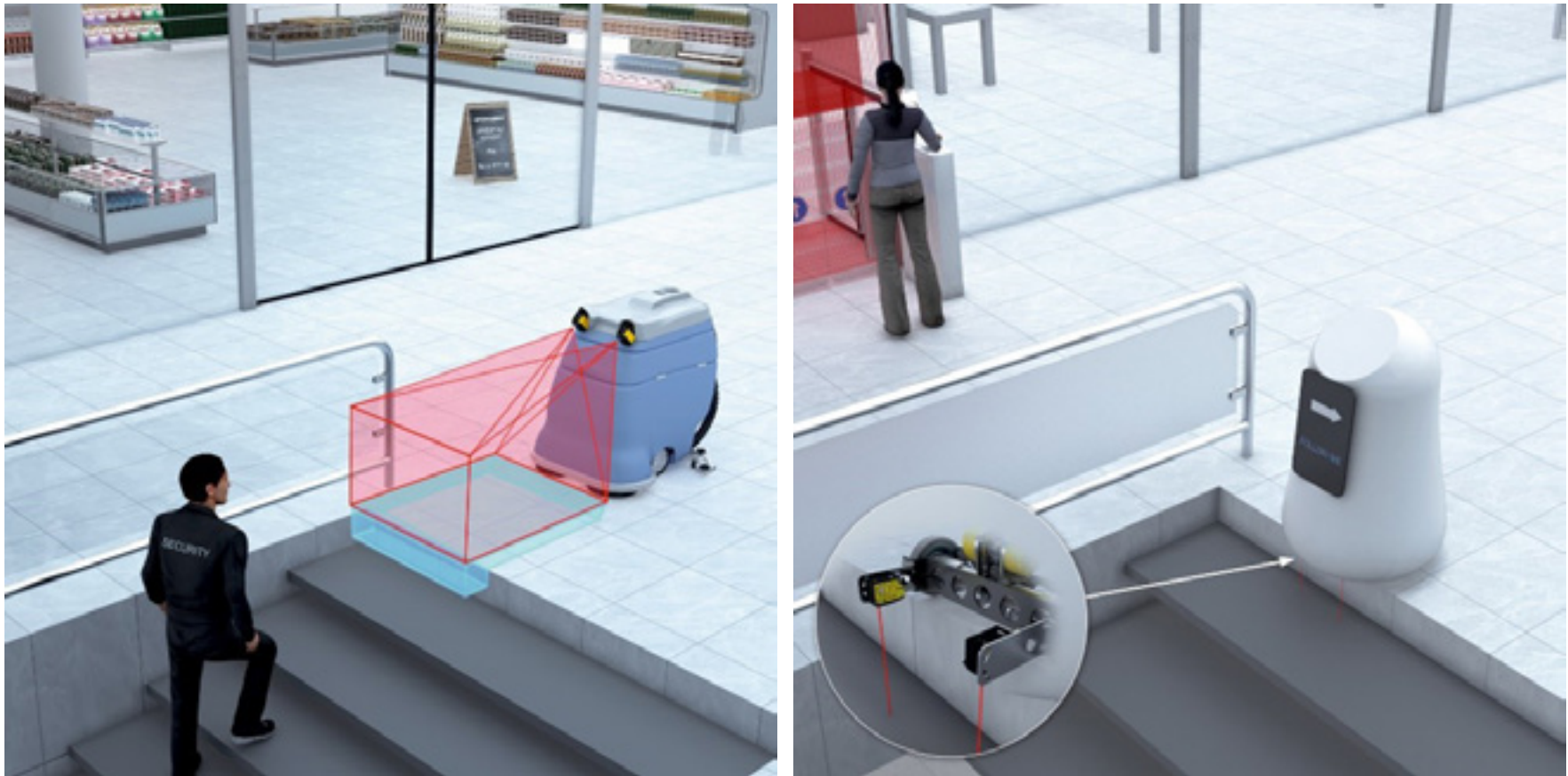


Challenges for mobile robots and AGVs at load transfer points and obstacles

If AGVs are not guided along a fixed route, the requirements change. For example, if there are steps, ramps, elevators or the like in the operating area of the vehicle, reliable detection of height differences in the direction of travel is necessary.

Here, safety laser scanners, camera systems or distance sensors assist with “cliff detection”, which must be selected based on the results of the risk assessment and the required PL_r.

Loads must be held in the correct position during transport to prevent them from falling or overhanging. For this purpose, vehicles usually have mechanical safety devices. If the load is not in the correct position, the AGV will not move or it will stop.¹² The use of safe inductive switches is one method of ensuring this.



Challenges for AGVs at load transfer points and obstacles

If the hazard to people cannot be ruled out at a load transfer point, the conditions of an operational hazardous area apply.¹³

Additional hazards arise at load transfer points depending on the area of operation:

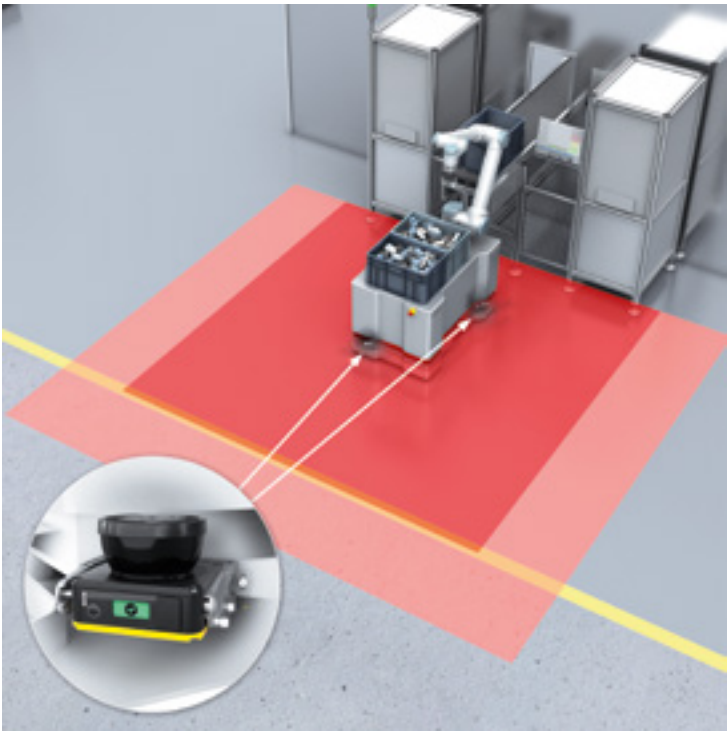
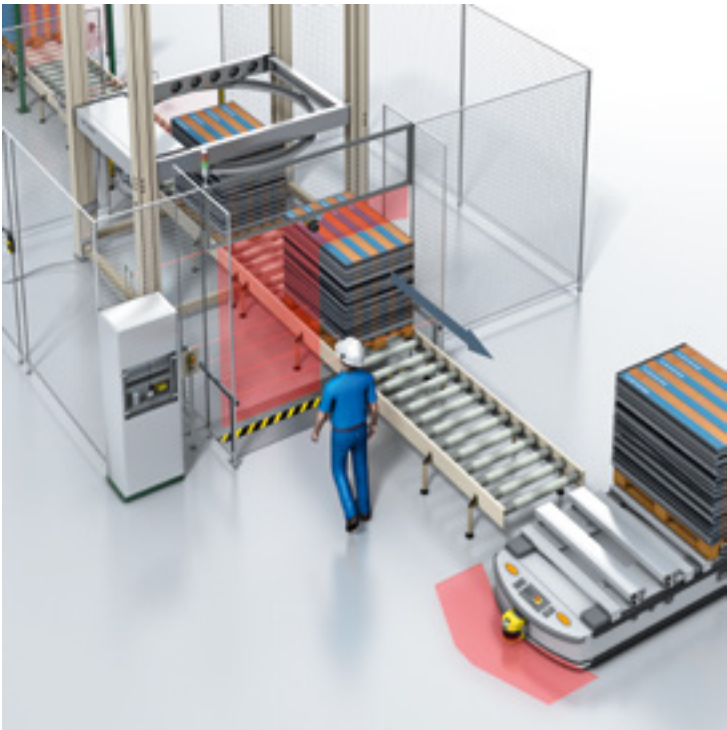
- Crushing of body parts: the minimum distance between the AGV and the side front covers of the conveyor belts in relation to the fingers is 25 mm.¹⁴
- Shearing points between the AGV system and conveyor: if the load transfer processes are outside a restricted or closed zone, they must be designed in such a way that the risk of injury to persons caused by the rigid part of the AGV (e.g. chassis, forks) or its load is reduced.

If additional hazards arise as a result of the load transfer process, it may be necessary to reliably detect the position of the AGV. Once this has been done and the additional safety features are active, the process can start.

If a robot becomes active at a certain time (for load transfer or material processing), the position of the mobile robot must be reliably detected and the protective field of the scanner must be switched from safeguarding the route to the safety area for the robot’s work.

This position can be achieved via safe contour detection – a function on the laser scanner – by the safety laser scanner. Further detection options include safe RFID or localization.

If there is remote access to the AGV controller, the safety function must remain active.¹⁵ If access occurs, additional measures must be taken to ensure that no people are in the hazardous area. If the safety software is changed through remote access – e.g. through an update – the safety function must be validated again on site. There is a need for action, especially with regard to the future requirements for cybersecurity within the framework of the EU Machinery Regulation.



Best practices

Tailored solutions for production and logistics

Innovative safety technologies and efficient automation systems play a crucial role in the modern production and logistics environment. As one of the leading providers of sensor solutions, SICK has developed tailored solutions in collaboration with Gessmann and IdentPro that not only increase efficiency, but also redefine safety standards in the industry.

Cooperation with Gessmann & advice on CE marking



Cooperation with Gessmann

As part of the cooperation between SICK and Gessmann, an innovative solution for the automated transport of razor blades was created at Wilkinson Sword. The use of **GESSbots**, which safely transport the blades between different finishing processes, significantly increases production efficiency. This technology not only reduces the manual workload, but also improves safety and precision in the manufacturing process.

Further information on the [SICK website](#).

Advice on CE marking

Together with IdentPro, SICK has completed a comprehensive CE marking process for autonomous, driverless forklift vehicles in highly dynamic warehouse environments. IdentPro was able to overcome the challenges of CE marking thanks to SICK's cooperation and experience in the areas of safety technology and risk assessment.

Furthermore information can be found on the [SICK website](#).



Conclusion

Overall concept of legally compliant safety design

When designing and safely designing AGVs and mobile robots, compliance with legal requirements must be ensured through a detailed hazard and risk assessment of the entire application, including the environment in which the AGV is used. The use of harmonized standards – especially EN ISO 3691-4 – significantly supports the development process in achieving a safe application. A variety of innovative products such as safety laser scanners and camera systems are available to design the safety functions required to reduce risk.



Outlook for EU Machinery Regulation (EU) 2023/1230

With SICK as your partner, you are well prepared

A comprehensive risk evaluation and compliance with relevant standards are crucial. Collaboration between manufacturers, safety experts and certification bodies is essential to ensure that systems in practice meet legal requirements. The EU Machinery Regulation will impose stricter safety and cybersecurity requirements beginning 20 January 2027. SICK supports companies in adapting to the new regulations and offers tailored solutions to ensure the conformity and efficiency of the systems. Early adjustments to the new requirements ensure long-term safety and conformity of machines and automated guided vehicle systems.

On 20 January 2027, the EU Machinery Regulation (EU) 2023/1230 will replace the Machinery Directive 2006/42 / EC – up until 19 January conformity will be declared on the basis of the Machinery Directive and from 20 January onwards, this will be done on the basis of the EU Machinery Regulation.

Further information on the topic of the EU Machinery Regulation is available to manufacturers, designers and distributors [on the SICK website](#).



SICK – Solutions and expertise

Innovative sensors and know-how for maximum safety

SICK offers a wide range of sensors and system solutions to support the safe use of AGVs and mobile robots:

- **State-of-the-art 2D and 3D sensors:** for precise detection and navigation, e.g. [microScan3](#), [nanoScan3](#) or [safeVisionary2](#).
- **Flexi Soft:** compact [safety controllers](#).
- **Encoders, RFID sensors and inductive sensors:** for safe position, direction and speed detection.

In addition to the products, SICK offers extensive services, including consulting and training, technical documentation and long-term support. This support helps companies implement legal regulations and ensure the safety of their systems. The combination of advanced products and extensive expertise makes SICK a valuable partner in designing safe mobile platforms.



Contact and further information

SICK at a glance

SICK is one of the leading manufacturers of intelligent sensors and sensor solutions for industrial applications. With over 12,000 employees and more than 50 subsidiaries and equity investments as well as numerous representatives worldwide, SICK always ensures close proximity with its customers. A comprehensive range of products and services creates the basis for safe and efficient control of processes, for protecting people from accidents and for preventing environmental damage.

SICK has extensive experience in a wide range of industries and is highly familiar with their processes and requirements. With intelligent sensors, SICK delivers precisely what customers need. System solutions are tested and optimized according to customer requirements in application centers in Europe, Asia and North America. All of this makes SICK a reliable supplier and development partner. Comprehensive services complete SICK’s offering: SICK LifeTime Services provide support throughout the entire machine life cycle and ensure safety and productivity.

This is “Sensor Intelligence”.

Would you like to learn more about these options? Then visit [our website](#) or [contact us](#).

For further information and support in implementing the Machinery Regulation (EU) 2023/1230, visit the [SICK website](#).



Source references, footnotes and notes

