Person/object detection, warning in danger areas

Camera and sensor systems, intelligent software for mobile machinery (construction machinery – mining)

Safety and efficiency in the use of Non Road Mobile Machinery/NRMM and Commercial Vehicles/CV – Guideline for operators, manufacturers and supervisors

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The Network Construction Machinery NRMM CV
supports the quality and cost-effectiveness of processes to improve safety in hazardous areas of mobile machinery (NRMM = Non-Road Mobile Machinery) and commercial vehicles (CV).

The focus is on person and object detection for collision avoidance. Key tasks in this area are discussed with the stakeholders concerned. Practical information and guidelines are developed from the results.

Essentially, the information and solutions presented in this guide apply to mobile construction machinery and commercial vehicles (also referred to collectively in the guide as "mobile machinery") that move around construction sites, quarries or even the ceramic and glass industries.

Due to similar technology and comparable hazard potential, the information can also be applied to other vehicles and mobile machines. For this purpose, the network offers separate sector specific guides – (For an overview of the guides see page 47).

This network guide **"Person/object detection, warning in danger areas"** provides an overview of technical measures, such as:

- camera monitor-systems
- warning/sensor/assistance systems
- intelligent software for object detection
- AI-applications

These measures can support the driver/operator in case of limited visibility and provide reliable collision protection when using mobile machinery.

Entrepreneurs, managers, works councils, occupational safety specialists (SiFAs*), safety officers (SiBes*), safety and health coordinators (SiGeKos*), drivers/operators, manufacturers and building owners receive valuable tips for safe and efficient use.

*German abbreviation

INITIATIVE NEUE QUALITÄT DER ARBEIT

Good working conditions and economic success belong together!

The Network Construction Machinery NRMM CV acts in the spirit of the German "Initiative New Quality of Work" (INQA) of the Federal Ministry of Labour and Social Affairs (BMAS). INQA as a practical platform for quality of work and the change of work connects companies with expertise, practical experience and a broad network with concrete offers, which are supported by social partnership.

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Contents

1 Detecting dangerous situation safely

Visibility and attention

During the operation mobile machinery, serious accidents - including fatalities - and property damage occur repeatedly due to persons and objects in the danger area not being recognized in time.

Restricted or missing visibility causes:

- Disturbances in the work process
- Stress for those affected
- Increased risk of accidents

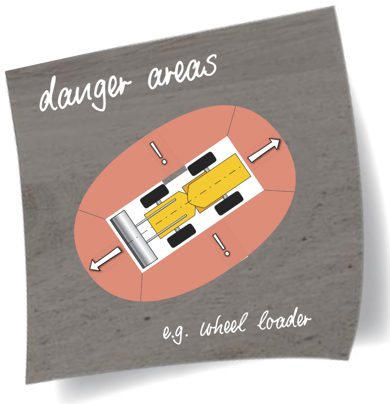
First requirement: Ensure visibility of the hazardous areas!

Definition of field of vision: Totality of all directions to the front and the sides in which the driver/operator can see.

Despite the improvements in driver visibility on mobile machinery, so-called "blind spots" can remain outside the **driver's field of view** due to the design:
the danger areas that cannot be seen directly from the driver's seat!

If the driver's direct view of his working area is not sufficient to safely recognize persons and objects there, technical measures, such as camera monitor systems (CMS), must be used as a matter of priority (see risk assessment chapter 1.1).

- **Therefore, before ordering and after delivery of a new mobile machinery, as well as when renting and purchasing an existing machine, it is essential to check whether the driver's view is good. In case of restricted visibility, technical measures must be taken first (TOP principle, see next page)!**



Prevention is the best way to avoid accidents

Therefore, always perform a visibility risk assessment before every work assignment – especially on new construction sites/locations.
According to German requirements for risk assessment, see ArbSchG (Arbeitsschutzgesetz) specified in TRBS 1111 (TRBS = Technische Regeln für Betriebssicherheit/Technical Rules for Operational Safety).

The risk assessment, which must be performed by the employer (according to the Occupational Safety and Health Act), is not to be confused with the manufacturer's risk assessment/hazard analysis (according to the Machinery Directive)!

1.1 Performing a visibility risk assessment

If the driver's/operator's direct view of the work area is not sufficient to safely detect persons and objects there, technical measures must be defined and implemented as a matter of priority in accordance with the "TOP principle".
Hierarchy of protective measures:

1. **Technical:** Use means to improve visibility, such as camera monitor systems that ensure adequate visibility. Also consider whether additional warning/sensor systems are needed for person/object detection.
2. **Organizational:** Define and mark hazardous areas, establish rules of conduct (e.g., prohibition of presence, guiding, marshall, security guards or barriers) and monitor compliance with them, provide regular instruction on hazards and the protective measures to be observed.
3. **Personal:** Provide personal protective equipment (PPE), e.g. high-visibility vests as a supplementary measure, and ensure that they are used.

Enable visibility of the roadway and hazardous areas

The view at the screen enables the driver to monitor the danger zone of the mobile machine.

First optimize the seat setting for the driver and then check it: Is there a direct view of the machine's danger areas, and

- Which mirrors are mounted?
- Are the mirrors in the correct position?
  Note the following: Mirrors and monitors must be mounted in the driver's front 180° field of view.
- Is the view sufficient? (see tip in right-hand column)

If not, implement and use the following technical measures or solutions:

- camera monitor system
- surround view camera system
- warning/sensor/assistance systems
- Intelligente, aktive Lösung

In special, unclear situations (e.g. when loading and unloading, in flowing traffic), instruct and use traffic signaller/marshalls.

Always identify possible hazards in the area of use of mobile machines and implement and document suitable protective measures according to the **"TOP-Principle"**:

- **T**echnical measures

always have priority over

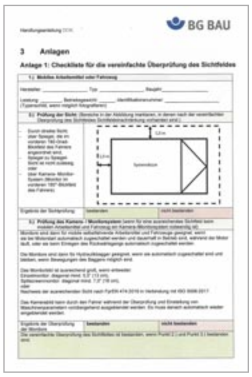
- **O**rganisational and
- **P**ersonal measures

The risk assessment must already be started before the selection and procurement of work equipment.

The requirements and criteria for the planned areas of use must be described and documented in detail.
This includes, for example:

- **application requirement**
- **experience of the employees**
- **state of the art in personnel and object detection systems**

TIP: Checklist for the simplified inspection of the field of vision


BG BAU
3 Anlagen
Anlage 1: Checkliste für die vereinfachte Überprüfung des Sichtfeldes

https://www.dguv.de/medien/fb-bauwesen/bilder/sicht_check-liste_0225docx.pdf

Second requirement: Enable the driver's attention

However, no one can constantly and fully concentrate on monitoring all the operations of their mobile machine or vehicle. The best visibility conditions and additional measures to improve visibility are only of use as long as the driver has all hazardous areas in view simultaneously and attentively. A loss of concentration can severely restrict his ability to react and cause additional hazards.

Causes of fatigue and declining responsiveness:

- High work intensity, time and deadline pressure
- Complex tasks
- Completely missing or insufficient risk assessments
- Unfavourable weather and visibility conditions
- Ergonomic influences
- Fatigue
- High noise levels, dense traffic
- Monotonous procedures
- Psychological stress factors

To prevent accidents in time and improve driver awareness, use sensory warning systems that support the camera monitor systems.

Photo above: A TAG-based system enables a person to be recognized – even behind a pile of scrap metal – here using RFID technology.

The sensory system warns the driver in case of acute danger. It sharpens his attention, for example, by means of a clearly perceptible acoustic signal. When looking at the monitor of the camera monitor system, the driver receives precise information about who or what has appeared in his working or danger area. In many cases, a camera is already fitted to the mobile machinery upon leaving the factory. In this case, it is advisable to add a sensory system to prevent a loss of attention.

Third requirement: Make machines smarter

Even if clear visibility is ensured and active warning systems ensure the best possible attention, many other tasks remain for the driver/operator that go far beyond the performance of an assistance system when maneuvering or driving (see also chapter 5).

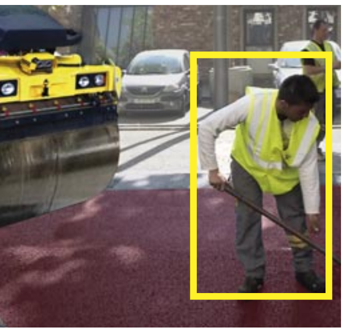


Photo above: AI based systems are also increasingly being used to protect persons in hazardous areas of mobile machinery.

Examples of assistance tasks that make mobile machinery "smarter":

- Preventive collision warnings
- Evaluation of hot spots (areas at risk of collision)
- Warnings on the operating status of the mobile machinery
- Lane keeping/guidance
- Display of machine data (consumption, performance, operating times, idle times)
- Status messages about attachments
- Information for preventive maintenance measures
- Support compliance with safety regulations

These and other tasks support partial automation and automation processes that are realized with a combination of robust hardware and intelligent software. Camera/sensor data and image processing technologies play a key role here.

Digitization provides the basis for making machinery "smarter"

Whereas up to now camera/sensor systems, according to their requirement-related specifications, have been working independently on the same tasks - for example, the detection of people and objects in hazardous areas – digitized processes enable further solutions.

Digital processes combine information from several integrated sensors. The measured data is acquired in parallel from, for example, a camera, an ultrasonic sensor and a radar system, which are evaluating simultaneously. This superimposition of sensor signals increases reliability in the detection of hazardous situations across the multitude of possible environmental scenarios. The result is used to trigger a previously defined system intervention.

When danger is detected, the system actively intervenes in the behaviour of a system in order to protect detected persons and bring the system back into a safe state: e.g., through an autonomously induced braking or evasive maneuver (see chapter 5).

Digitization provides the basis for simultaneous

- making machines more intelligent and
- increasing automation of business and work processes.

Digitization supports value-creating effects by optimizing business processes. Digitization requires and brings about permanent changes, up to and including "new forms of collaboration".

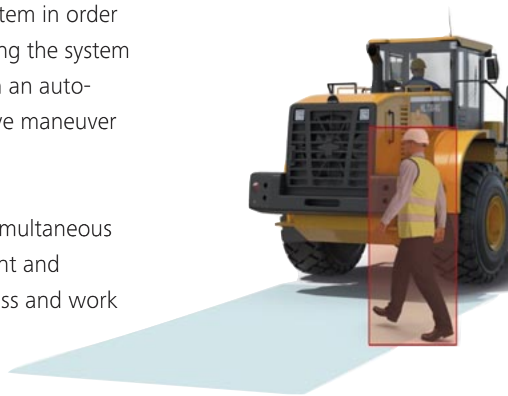


Image above:
Example of a wheel loader with AI camera – the AI camera system recognizes the person behind the vehicle.

INTERVENTION IN DRIVING BEHAVIOR	INTEGRATION
▪ Display of the environment on the vehicle monitor with hazard identification and acoustic warning	Installation of sensor technology, computing unit and visual display including visual and acoustic warning methodology
▪ Putting the vehicle in a ready-to-brake state (increase braking force boosting) ▪ Reduce acceleration ▪ Initiate braking process (autonomous braking) ▪ Intervene in steering behaviour (evasive maneuvers) ▪ Autonomous driving	Monitoring and active machine control ▪ Funktional Safety ▪ Safeguarding

Functional Safety

An assessment of functional safety is carried out taking into account the generally recognized rules of technology. The primary objective of "functional safety" is to reduce the risk of danger to persons. Functional safety concerns the control system of mobile machines on which a safety-relevant function depends. This is particularly relevant in autonomous systems for accident prevention.

If the behaviour of a system is actively intervened in the event of danger, this must always be evaluated and implemented according to the criteria of functional safety.

Industrial Security

With the increasing degree of networking in mobile machines and, above all, the increasing opening up of previously internal data/communication networks and components, "industrial security" is also gaining in importance.
The risk of an external attack and the possible manipulation of software and data associated with it is increasing. This can have serious consequences for security. Industrial security is thus becoming the focus of attention at all levels and phases of development and operation. The main objectives of Industrial Security are confidentiality, integrity and availability of data and software functions.

▶ Functional Safety: Protection of people from machines (occupational safety); design measures to make machines safer so that safety-related control systems can reliably perform their safety functions.

▶ Industrial Security: Protection of the machine against attacks by third parties; safeguarding of information technology in industrial plants, machines and systems (cf. VDMA: "Leitfaden Industrie 4.0 Security").

2 Sight and visual aids

Camera Monitor Systems (CMS)

2.1 Standard camera monitor systems

Camera monitor systems (CMS) are auxiliary devices for improving visibility in the working and movement area of mobile machines. They support the monitoring of hazardous areas in front of, behind and around a mobile machine – both during driving movements and during movements of attachments and front components.

The photo above shows the display on the monitor – using the example of an excavator.

Use Case: the rear camera on a wheel loader provides a view of the rear working area

When using CMS, respect following requirements:

- CMS are to be used exclusively for monitoring the close-up area around the machine.
- CMS are not intended to perform prolonged driving movements.

Direct vision has top priority!

Examples for heavy duty cameras and a waterproof monitor

Systems for improving visibility and detecting hazards

Anyone driving vehicles or mobile machinery with poor visibility is exposed to considerable mental stress.

Standard camera monitor systems have proven their worth in improving visibility and speeding up hazard detection when using mobile machinery and commercial vehicles in quarries, on construction sites, etc.

Avoiding accidents and hazards due to restricted visibility

The implementation of modern technology enables safer work processes, encrease of ergonomic and much more effectiveness.

Seek qualified advice from a specialist company on the fields of application and particular advantages of the systems described for improving visibility and additional hazard detection.
This includes comprehensive information on important technical and optical requirements for camera monitor systems, such as:

- Camera opening angle
- Display quality of the monitor, such as resolution, contrast, color accuracy
- Transmission time of the image data
- External influences
- Alignment of camera and monitor

Please note that the use of CMS helps or enables the driver to see into areas that are difficult to see – but without actively warning them of a collision. The use of a person/object detection system is required to actively warn the driver (see chapter 3 and 5).

For retrofitting, always follow the manufacturer's instructions for the mobile machinery and the camera monitor system used!

A controllable field of vision for the danger zone enables faster, more precise and safer work.

The monitor gives the driver an insight into the close-up field of his machine, enabling him to recognize a person at risk and react to the situation.

What does DIN EN 1175 say about monitor selection?
According to DIN EN 1175, monitors should have a minimum size of 7 inches at a viewing distance of up to 1 m. The person at risk must be displayed on the monitor in a minimum size of 7 mm (ISO 16001).

- **Recommendation from practice:**

For ergonomic and safety reasons, monitors should be **at least 10 inches in size** – with a viewing distance from the driver to the monitor of up to 1 m.

2.2 Surround view camera monitor systems

270° to 360° all-round view (surround view)

Advanced camera monitor systems enable 270° to 360° surround views. Their use can support the workflows of mobile machines.

Please note:
Attachments should not exceed a height of 4 m (passages, bracing, electrical cables).

Photo above: Surround-view cameras provide the operator with an overview of the immediate surroundings. An all-round controllable field of view enables fast, precise and stress-free work, even in special applications with e.g. high capacity buckets for light materials. (See also DGUV publication "FBHM-109: Radlader mit Leichtgutschaufel").

Bottom image: Components of an surround view CMS, consisting of 4 cameras, a monitor and a control unit.

Retrofitting:
Starting with a rear-view camera, it can be expanded to up to four cameras and up to an surround view system.

From rear to surround visibility

The big advantage is the simultaneous display of all relevant areas around the mobile machine: the operator grasps all hazardous areas of his immediate machine environment with a single glance at the monitor.

Always under the condition that the driver/operator can quickly and clearly recognize potential hazards on the monitor display, even in the event of stress!

Modern standard components enable a 360° all-round view on the monitor if the camera images are arranged and displayed appropriately. Individually and application-related, the camera images show areas required for hazard detection and thus offer a high degree of safety.

Individual camera images can be displayed maneuver-related as full screen or split screen. They allow a view around the entire vehicle and/or a targeted view of adjustable areas.

For optimal use, the quality of the cameras and the monitor are crucial important.

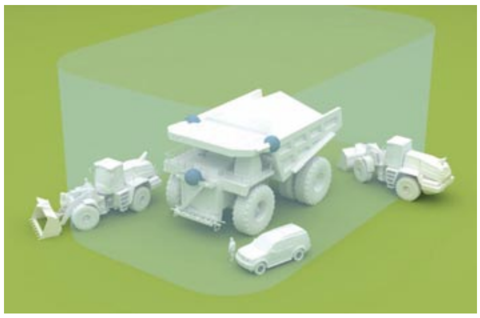


Image above: Illustration of surround view arround a dumper.

System selection – solutions for different applications

Surround view camera monitor systems (also known as 360° CMS) are available in several technical solution variants – see gray box on the right. For the driver/operator, the differences are most apparent in the way they are displayed on the monitor.

When selecting a suitable system, it is essential to consider the respective different requirements of work environments!

Where and how the system will be used:

- **on which type of machinery?**
  and
- **for which specific work application?**

In harsh environments, as with standard CMS, all components outside the cabin (cameras, cables, connectors) should be suitable to be cleaned with high-pressure cleaners, cameras and monitor should be shockproof. (IP69K).

Technical options:

- Event-controlled image switching for a separate and enlarged display of the respective area, e.g. image display of the rear camera when reverse gear is engaged.
- Optional, e.g.: Day/night switchover of the monitor (manual or automatic), brightness compensation for cameras, heated cameras.
- In addition, CMS can be supplemented by sensors (see chapter 3 and 5).

Operating principle Surround view CMS

Real-time imaging of the environment around the machine can be achieved in different ways – based on the use of 4 cameras in each case (or 3 cameras for a 270° view, depending on requirements):

1. Surround view in bird's eye view:
Simultaneously generated digital images of the cameras are further processed by video stitching and combined to a 360° image.
The monitor shows a bird's eye view (2D top view or 3D view) as a single view or optionally several views in split screen.
(see chapter 2.2.1)

2. Surround view from 3-4 singles views:
The images from four standard cameras are arranged to form an all-round view and displayed on the monitor next to/above each other.
(see chapter 2.2.2)

Explanation of terminology:

"Real time" describes the transmission within permissible latency values.

"Latency" refers to the time delay between the real event in front of the camera and the display on the screen.

Which system is suitable depends on the type of mobile machinery (e.g. wheel loader, excavator) and the application.

On the following pages, the different possibilities for surround view are explained in more detail. ▶▶▶

Graphic on the right:
Example of a surround view CMS with integrated sensors.
The driver/operator is warned as soon as a person or object is in the danger zone.

Photo left:
Monitor of a surround view CMS in the driver's cab of a wheel loader.
The driver can see the near field around his machinery and at the same time observe the rear area in close-up.

2.2.1 Four cameras – surround view from a bird's eye view (birdview)

Component examples: Monitor, computing unit and cameras

Real-time optimized images from the CMS provide a better overview for even safer maneuvering at low speeds. Ultra-wide-angle cameras mounted on the mobile machine – front, rear and side – show the respective vehicle surroundings.
The images from the cameras are combined into an surround view via the control unit (ECU) (video stitching). The driver/operator can watch the situation and any endangered persons and objects around his vehicle at a glance.

Software integrated into the CMS removes distortions and "fish-eye" effects that can occur with very large camera angles. The software produces a clear, distortion-free image in the form of an all-around bird's-eye view.

Application examples illustrate how the bird's eye view ("birdview") is displayed on the monitor in the driver's cab.

The three photos on the left show a 360° system on a dumper truck (photo above: monitor view; photos below: mounted camera):

- CMS gives the driver/operator a realistic surrround view of his mobile machine.
- In addition to the surround view, he can also display individual areas – either as a full screen or in split-screen mode.

Positioning of a 360° system – here the right side camera – on a dumper

The other practical example (photo below on the right) shows the monitor view of a 270° system:

- Three wide-angle cameras allow the rear and side areas around the mobile machine to be monitored.
- As an option, a fourth camera can be installed to monitor cargo or attachments, for example.

Please note:
Camera calibration is performed at ground level – objects/persons higher than the calibration level of the camera are displayed larger, as the camera angle to the object/person changes.

During excavation work, the raising and lowering of the excavator arm can lead to distortions in the display. An additional camera that is automatically activated when panning to the right may be helpful here.

Other possibilities: Specific requirements resulting from the work application or the type of mobile machine and its attachments may require special measures.
For example, the front camera can be positioned in such a way that it can also see over a high-volume bucket (not exceeding a total height of 4 m with the attached parts).

2.2.2 Four cameras – displaying a surround view combined from individual views

The images from four standard cameras are compiled into an all-round view and displayed on the monitor next to and above each other. **The flexible arrangement of the cameras allows the driver to react individually to the vehicle and to the specific operating situation.** Monitors with split-screen technology support optimum visibility for mobile machinery such as wheel loaders, excavators and quarry vehicles like tippers, dumpers and heavy trucks.


Visualization of the fields of view of a surround view CMS


Example of monitor with split screen display

The control of individual camera views can be set up manually or via vehicle signals, such as setting the turn signal or engaging reverse gear.

System features

- No calibration and calculation unit necessary
- Flexible choice of aperture angle and mounting position of the cameras so that all areas around the vehicle can be viewed (even at the corners)
- Individually adjustable triggers for different perspectives
- Automatic, application-specific display of the cameras – e.g. view to the right when turning right
- Integrated preset for appropriate arrangement of camera images for uninterrupted real-time image playback
- 3 to 4 wide-angle cameras for capturing the entire vehicle area and surrounding area; aperture angle of 100° to 130° – selectable according to the desired camera position and machine size (depending on the machine size, cameras with a smaller angle of view may be suitable)
- Optional retrofit capability for a wide range of applications
- Fade-in guidance lines provide additional orientation
- Adaptable viewing areas and distances to suit vehicle type and application


Component examples above: Monitor with split-screen display and one of four cameras – with and without heavy-duty housing

Surround view CMS in different work areas

270°-/360°-CMS can be configured for different mobile machinery or commercial vehicles and for multiple task areas. Depending on the specific environment and application, particularly robust cameras may be required.

2.3 Mirror Replacement systems

"Digital exterior mirror"

Conventional exterior mirrors mounted on the vehicle often do not provide sufficient support for the driver in terms of work and requirements, especially on large machines that are difficult to maneuver. The use of a digital mirror replacement system – also known as a 'digital exterior mirror' – can provide a remedy here. **One particular advantage is that the cameras have a wide viewing angle and can be positioned in such a way that the driver has an optimum view of the danger zone.**

Retrofitting:
Digital mirror replacement systems can be retrofitted to various types of off-road vehicles.

Anti-reflective displays and special protective coatings on the camera housing provide additional robustness against environmental influences.

Component examples: two HD cameras and a bright display with split-level mode

Protected from external impact, the displays/monitors are located inside the driver's cab, where they can be mounted in an ergonomic position.
Displays and cameras can be customized to the respective application and special requirements.

One or two high-resolution cameras per display provide the required images of the danger zone – **reliably even in backlighting, direct sunlight and darkness thanks to the HDR function** (HDR = High Dynamic Range).

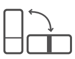
System features:

Razor-sharp and reflection-free images of the surroundings:

- High-resolution HD cameras with
- HDR function for brilliant image quality even in difficult lighting conditions,
- high-intensity and reflection-free displays with
- sensor for adjusting the brightness to the ambient light.
- In addition: 90° rotatable display for an application-orientated display.

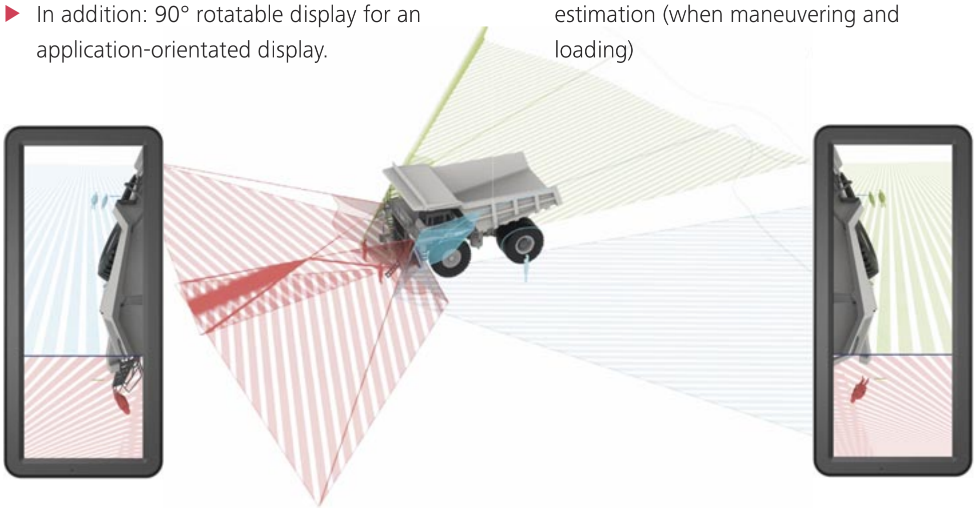
Functions that can be set via remote control, such as:

- Zoom for customized image sections (magnification in 10 steps)
- flexible image division (at a ratio of 1:1 or 2:3)
- Fade-in and freely movable, colored guide lines to support distance estimation (when maneuvering and loading)



rotatable screen

Depending on the requirements, a vertical or horizontal alignment of the display can be selected for viewing the danger zones – with a 1:1 (see illustration above) or 2:3 (see illustration left) image division.



Dump truck application example: The camera images of the danger zones are displayed in the digital exterior mirrors. The driver can individually set the views relevant to him and have additional colored reference lines displayed.

2.4 Transmission technologies of CMS

Various data transmission options are available for analog and digital CMS applications:

- **Cabel:** The image from the camera is transmitted to the monitor via a video cable.
- **Radio:** A digital radio link (transmitter and receiver) is set up between the camera and the monitor (see description below). In an "integrated" radio system, the transmitter is directly integrated in the camera and the receiver in the monitor.
- **WiFi:** The image from the camera is transmitted via a connected Wi-Fi transmitter to an app installed on a smartphone or tablet.

Wireless digital image transmission

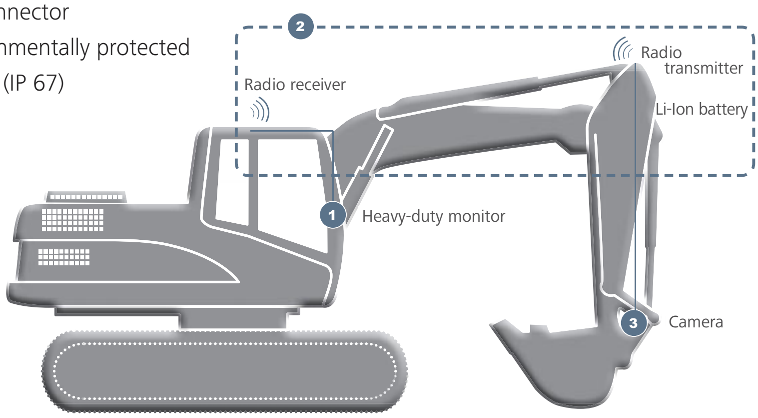
In some cases, it is difficult to implement cabling on the mobile machine, for example, due to a narrow design or deflection points susceptible to cable damage. Digital radio systems for wireless transmission of image data offer practical alternatives by means of robust transmitter/receiver units. Compact radio units send digital signals from a camera to a monitor quickly and without delay (possibly with low latencies). Depending on the system, up to 10 pairs of units operated in parallel allow a high degree of flexibility in adapting to a wide variety of machines, visibility problems and installation requirements.

When selecting a system, look for one with stable, low-interference and end-to-end encrypted digital radio.

The use of digital radio systems for wireless image transmission is characterized, for example, by:

- No need to lay cables on the machine
- Operating time of up to 28 hours
- Insensitive to interference due to 2.4 GHz digital radio; WiFi 5 radio standard (IEEE 802.11ac)
- Applicability to all types of construction machinery
- Simple, flexible installation
- Shock and vibration resistance of the complete system unit including integrated battery operation
- Low power consumption
- Robust industrial connector
- Weather and environmentally protected system components (IP 67)

Photo on the left:
Wheel loader with large volume bucket, which severely restricts the direct view to the front – a CMS with radio connection can be used here as a technical measure.



The graphic shows components of a digital radio system for wireless image transmission.

Larger sources of electromagnetic interference may cause problems with radio transmission – minor interference is compensated for by the frequency-current method. If the KMS fails, work must be stopped! For this reason, a cable connection is currently preferable.

2.5 Classic systems compared to AI-based cameras

Graphic above:
Representation of person detection in the rear danger zone of a wheel loader through the AI camera mounted at the rear.

The described camera systems serve as visual aids for the driver/operator. Increasingly, camera systems with person detection are being used. These combine the ability to visually monitor the danger zone with targeted warnings of imminent collisions with people (and, if necessary, with defined objects). Artificial intelligence (AI) plays a crucial role in their development (see chapter 5).

AI-Based Cameras for Person Detection

AI-based cameras for person detection offer an advanced, flexible, and more accurate solution by utilizing machine learning.

AI-based cameras used for person detection differ from classical systems primarily in the way detection is performed:

Intelligent Algorithms:
AI-based cameras use machine learning and deep learning, particularly neural networks, to detect people. They learn from large datasets and can thus recognize complex features such as different poses, facial expressions, clothing, and environmental conditions.

Higher Accuracy:
AI-based cameras offer higher accuracy in person detection, even under challenging conditions such as poor lighting, partial occlusions, or varying angles.

Advanced Features:
These cameras can extract additional information, such as gender and activities, providing more advanced analytical results.

AI-related topics such as "Machine Learning" are explained in more detail in chapter 5.

Classic Systems for Person Detection

Classic systems are generally more rigid and offer lower detection accuracy, as they rely on fixed programmed algorithms.

Rule-based Algorithms:
Classic systems for person detection often use simple, rule-based methods that rely on fixed algorithms and thresholds.
They frequently work with traditional image processing techniques such as edge or color pattern recognition.

Limited Adaptability:
These systems are less flexible and need to be manually adjusted for each new situation. They are more prone to errors when there are changes in the environment or when unexpected scenarios occur.

Lower Accuracy:
Classic systems are less robust to variations in the representation of people, such as different poses, clothing, or lighting conditions.

Simpler Functionality:
They typically offer only basic detection functions without deeper analysis or additional information.

3

Person and object detection

Warning and assistance systems

▶ Detect hazard all the times!

A CMS alone cannot guarantee concentrated work full-time. In addition object recognition systems can also support the driver/operator if the concentration level drops.

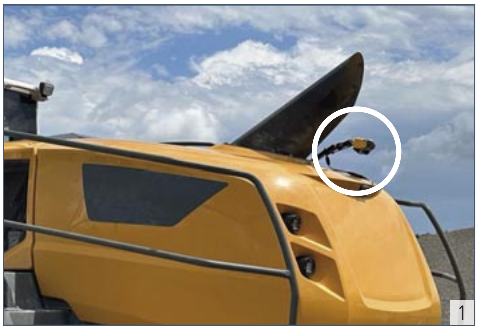
Prevention is always the best way to avoid accidents. Therefore, always carry out a risk assessment – see chapter 1.1!

▶ Areas of application according to function

Warning/assistance systems support person and object detection when entering/working in areas that are difficult or impossible to see. that are difficult or impossible to see in. They improve the prevention of accidents. To increase safety, the detection systems can be configured for a wide variety of work tasks and hazards. Depending on the requirement profile, different sensor systems are used, subdivided according to their operating principle, e.g.

- **Ultrasonic systems**
- **Radar systems**
- **Lidar systems**
- **Transponder/TAG based systems**
- **3D cameras sensors**

Essential factors are the selection of the right system for the application according to their respective and the quality of the system used. Other technical solutions can be used for special tasks – ask your specialist company.



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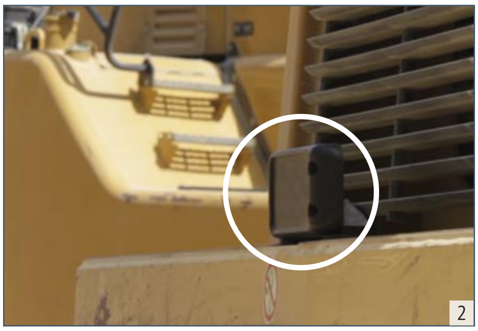

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3

4

Limited space requires the highest level of attention. In addition, long-lasting or monotonous activities can cause the driver/operator's concentration to wane, resulting in a higher risk potential.

Person and object detection systems can effectively prevent this, for example by means of:

- Intelligent person/object detection using 3D camera sensors (Fig. 1)
- Radar systems for rear area monitoring optionally with additional camera view (Fig. 2)
- Ultrasonic sensors for comprehensive rear and side area monitoring (Fig. 3)

For enclosed company areas/construction sites with entrance/personnel control transponder/TAG based systems that warn the operator of the vehicle and persons and vehicles approaching the danger zone (Fig. 4).

3.1 Ultrasonic systems

Figures above: Ultrasonic sensors on a concrete pump; below: Display on the monitor in combination with a CMS.

Examples for components of an ultrasonic system:

Sensors, control unit, signaller

▶ Maneuvering safely in confined areas

Tight working environments demand special attention from the driver. Here, large-area detection of obstacles is a typical task for ultrasonic sensors in mobile applications. If persons or objects enter the detection range of the sensors, an acoustic signal warns the driver: immediate stop becomes possible!

▶ Detect objects with high precision at low speed

Ultrasonic sensors detect obstacles (persons and objects), with a very high accuracy of up to 1 cm (depending on the driving/maneuvering speed) in the immediate vicinity: at distances of up to 3 m (in individual cases even at distances of up to 9 m) from the vehicle/machinery.
The detection range can be set according to requirements.

▶ Proven on a wide variety of vehicles in many industries

Ultrasonic systems with their precise object detection enable a continuously monitored approach, for example when loading loading dumpers.
It makes sense to use ultrasonic systems in confined spaces, e.g. when driving into public road traffic.

Depending on the working area and the hazardous situation, ultrasonic-based distance warning systems are available in different configurations.

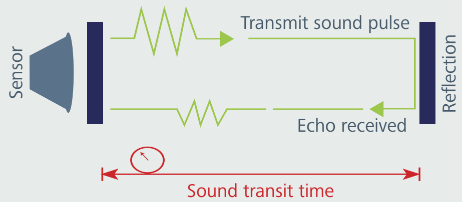
According to the requirements (vehicle/machine type, work task and environment),

- rear,
- lateral and/or
- front

ultrasonic systems are used.

ATTENTION:
In case of very high levels of contamination due to dust, smoke or moisture, false alarms may be triggered.
Faulty signals can impair the willingness to heed warning messages..**Therefore, always check the place of use and the task area and carry out a visual risk assessment** (see chapter 1.1).
Useful: Some systems detect sensor soiling and inform the driver/operator when that happens.

Operating principle of ultrasound (ultrasonic waves)



The distance to the object is calculated from the time difference between sending and receiving a sound pulse with a frequency of >20 kHz (optimally 40 to 60 kHz).

Ultrasonic systems can register several objects simultaneously. For example, the object closest to the machine can be communicated via the display. As soon as an object leaves the danger zone, the display reports that there may be other potential dangers in a warning zone.

Examples of
ultrasonic sensors for distance measurement

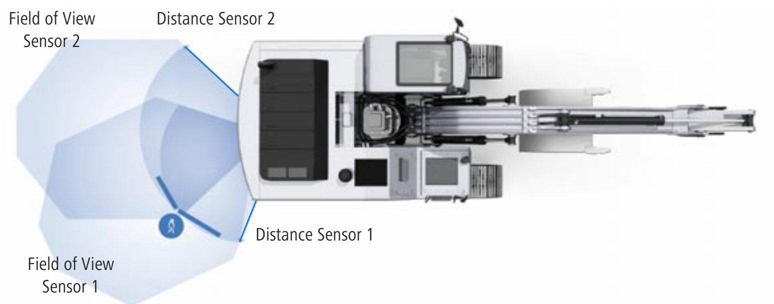
Features for ultrasonic systems

During procurement, special attention should be paid to the following features, among others, and a specification sheet with the specific on-site requirements should be prepared beforehand:

- Detection independent of material colour, transparency, gloss and ambient light (also glass, liquids, foils).
- High accuracy due to time-of-flight measurement
- Insensitivity to light dirt and low humidity
- Multi-level, auditory distance warning system
- Measurement sensitivity flexibly adjustable
- Ambient learning mode to avoid false alarms
- Synchronization and multiplex operation, self-diagnosis, visual distance display

When driving and maneuvering in confined working areas, ultrasonic systems can help to avoid collisions.

Ultrasonic systems consist of several sensors and a control unit (ECU = Electronic Control Unit), see image on the right. **The ECU processes the distance data received from the sensors.** Data is exchanged via the CAN interface (CAN = Controller Area Network).



Images above: Two ultrasonic sensors mounted at the rear detect the rear close-up area of the excavator. Objects located in the detection zone are detected by the sensors. By precisely determining the object position in the area, the machine operator is supported even better in identifying hazardous situations.

Ultrasonic systems can monitor the working areas of mobile machines and vehicles. In doing so, ultrasonic sensors (system-dependent) work under all weather conditions. They are able to detect objects regardless of colour, surface and environmental influences.
The detection area can be divided into several, adjustable danger zones. Some systems allow the exact detection of the position of a detected object in space. The signals, which can be differentiated according to the respective danger zone, inform the operator/driver about the distance to the object or person in the danger zone.
A complementary camera-monitor system provides the warned driver with visual information about the nature of an obstacle: he can recognize and better locate the obstacle.

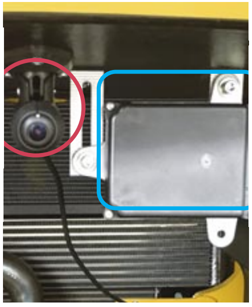
Ultrasonic systems can have numerous configuration options, such as:

- Distanzfilter Distance filters to mask out interfering elements in the field of view
- Sensitivity options for optimal adjustment
- Intelligent transmission and filtering algorithms to avoid signal interference or to reduce external interferences

The issue of safety-relevant functions for environment detection is becoming progressively important. For the off-highway sector, first safety variants in accordance to the EU-Machinery Directive (MRL) with Performance Level D will be launched on the market. Specifications for this are regulated by the EN ISO 13849.

3.2 Radar systems

Image above: radar sensor in combination with a rear-view camera
Image below: radar sensor (marked blue) in combination with a rear camera (marked red)



Reliable warning even in limited visibility conditions

Radar systems detect persons and objects very reliably even in harsh environments: thanks to their high resistance to dirt, mud, dust, heavy rain, humidity, heat, cold (optionally equipped with heated sensors), UV rays, vibrations and storms. They also function reliably in darkness, fog, smoke and poor visibility in general.

Radar systems are ideally suited for use even in the most difficult conditions on construction sites, in mining, agriculture and forestry.

Detecting objects in a 20 m radius at high speed

Detection and locating methods based on electromagnetic waves can reliably detect large detection areas up to distances of 20 m away from the vehicle, even at speeds of up to 20 km/h.

Warning with very short delay

Warning systems with radar sensors support the driver with a very low time delay (50 ms) when detecting objects.
They help avoid accidents in the danger zone of a vehicle and make maneuvering and reversing easier. This applies to construction machinery (civil engineering, quarrying, track construction, mining) as well as mobile cranes, agricultural and forestry vehicles and industrial trucks.

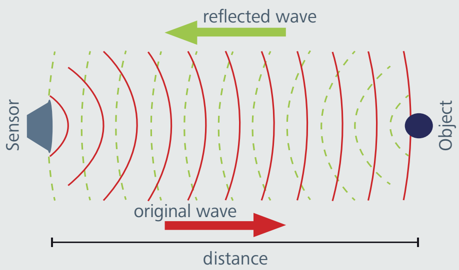
Radar systems usually comprise one or two sensors. These can be mounted specifically where the respective danger area of the machine/vehicle is to be monitored.
The detection area is divided into several zones so that the operator/driver is informed of the distance to the object or person by appropriate signals (see figure in box on right).

Ergänzt durch Kamera-Monitor-System besonders wachsam

Radar warning systems provide additional safety for field-of-view monitoring of heavy machinery and commercial vehicles. Depending on the system, they can be directly coupled to a CMS or used independently.

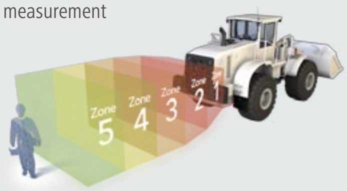
CAUTION: Check the vehicle's operating locations and task areas in advance and perform a hazard assessment: Impassable terrain can lead to unnecessary false alarms.

Operating principle of Radar (electromagnetic waves)



Electromagnetic waves transmitted by the radar as a primary signal are reflected by the object at the speed of light and received again as a secondary signal.
The measured time between sending and receiving results in the distance to the object.

Radar sensor for distance measurement



Features for radar systems

When procuring radar systems, special attention should be paid to the following features, among others, and a specification sheet should be drawn up beforehand with the intended application requirements:

- Multi-level distance warning system; determination of the exact object position if necessary
- Adjustable detection areas/zones
- Low time delay for object detection (50 ms)
- Acoustic and/or optical warning signal
- Expandable for additional applications (such as reversing alarms)
- Sensor blindness monitoring and filter for ground reflections

Radar sensors can be used on different mobile machines – on a small compact loader (photo above) as well as on a large dumper.

Picture above: The display in the operator's cab signals whether an object is in the danger zone of the working machine – and whether it is approaching or moving away from it.

Additional option: CAN bus-capable radar systems provide an interface for possible active vehicle intervention.

Comparison of radar system functions

Depending on the radar technology, the position of a detected object can be output exactly or in zones.
In addition to determining the position, modulating radar sensors also allow tracking the collision course of detected objects and differentiation between stationary and moving objects. The graphic on the right illustrates object clustering for more detailed environmental information in the field of view.

pulsating signal

modulating signal
(enables object tracking)

The radar sensor detects and recognizes fixed and moving obstacles with the aid of electromagnetic pulses. An active warning is issued to the operator/driver - as an acoustic and/or visual signal.

The operator/driver can detect the changing distance between the machine and the object:

- A faster sound sequence signals the approach of the endangered person(s) or the objects located in the danger zone.

- The corresponding visual representation of the hazardous situation is shown on a display in the driver's cab.

Combination of radar system and CMS: The photo shows the warning display of the radar system and the monitor of the CMS in the driver's cab.

The first high-resolution radar systems (= "4D Radar", "High Imaging Radar") will come onto the market for the off-highway sector. These provide a detailed spatial image of the surroundings and offer ten times higher resolution.
Objects very close to each other can be differentiated even more reliably (separation capability). The position of objects can be determined with ten times greater accuracy, which enables very precise lateral and axial measurement, for example for automated lane keeping.

3.3 Lidar systems

Laser scanning for precise detection

Lidar or Ladar ("Light/Laser Detection and Ranging") is a method for optical distance measurement using a laser beam and delivers very precise results. The detection is robust to lighting conditions of the environment and can be used even in complete darkness.
It is characterized by:

- Large measuring range
- Large horizontal aperture angle
- High resolution

Depending on the quality of the measurement process, the system is insensitive to dust and precipitation.

Data fusion

Based on object measurement and classification by laser pulses, the signals from the lidar system can be used directly for person/object recognition. By means of a software interface, a large number of parameters can be directly processed and visualized.

Key technology for assistance systems

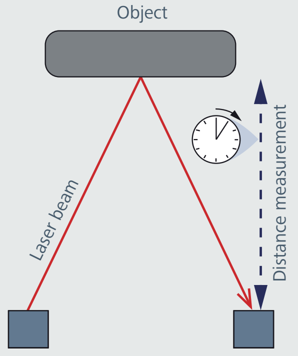
Lidar systems have long been used for environment detection and object recognition in port logistics, robotics and automotive assistance systems for passenger cars and commercial vehicles. In the development of autonomous vehicles, they are considered one of the key technologies.

Continuous further development is leading to increased use of lidar systems in mobile machines such as construction, mining and agricultural and forestry machines. The decisive factor for off-road applications is a robust sensor in which external influences, such as vibrations, do not impair the measurement result.

For off-road use, sensors should be installed in robust housings (up to IP69K).

The example shows a driverless mining vehicle analysing its surroundings with the aid of a 3D LiDAR sensor.

Operating principle of Lidar (pulsed laser beam)



The laser emits a pulsed – i.e. not continuously, but in temporal portions – laser beam which is reflected by the object. The reflected beam is received by a detector and the time between transmission and reception of the reflected light beam is converted into a distance indication.

Unlike a continuous wave laser, the pulsed laser has a higher power density. Lidar's optical power density is designed to be eye-safe (laser class 1).

3.4 Transponder/TAG based systems – LPS/RFID technology

Definition:
TAG = short term for the warning unit/unit of a transmitter-receiver system
Transponder = compound term made up of “transmitter” and “responder”

On construction sites, in tunnels and quarries where construction machinery and commercial vehicles (e.g. dumpers, delivery vehicles) with bulky loads are used, drivers' field of vision is considerably restricted – and therefore the risk of collisions between vehicles and persons/pedestrians and between vehicles and vehicles is high. TAG-based systems (also known as transponder systems) can significantly improve safety here. They make it possible to detect persons and vehicles equipped with TAGs (= detection/warning units), even if there is no direct visual contact between the sensor and the TAG.

▶ Warning on approach

TAG based systems alert when vehicles/mobile machineries und persons are getting too close. They provide two types of alerts with different detection intervals: **pre-warning** and **warning**.

The visual and audible alarms allow the presence and position of workers equipped **with active TAGs** to be displayed in real time in hazardous situations, thus mitigating critical circumstances caused by poor visibility.

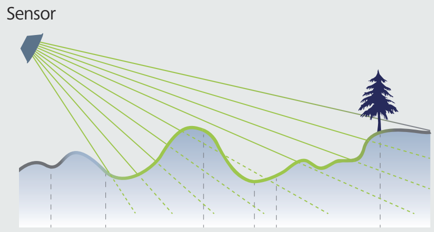
If a person enters a danger zone,

- the **driver** alerted with a visual and audible warning. He can see on the display in the driver's cab exactly where the pedestrian is located.
- **In addition:** the **pedestrian** is warned by the TAG, that vibrates and lights up in case of a collision risk.

▶ Requirements for a two-sided warning

- **Closed area**/operating site with access control (e.g. fencing plus gatekeeper).
- Each vehicle/mobile machinery must be equipped with a **sensor/warning unit "vehicle"**.
- Each person must wear a **TAG/warning unit "Person"**.

Principle Radio (electromagnetic waves)



Tag based systems use radio waves that can also extend as diffracted ground waves into concealed areas that cannot be seen. Depending on the technology used, a distinction is made between:

1. LPS – Local Positioning System
Technology that measures distances with centimeter precision and works via a TAG with a rechargeable battery (the TAG vibrates and lights up). The activation fields can be customized both in shape (6 modelable points) and size. LPS also allows real-time measurement of the risk level.

2. RFID – Radio Frequency Identification
Technology that creates detection areas with long distances. It uses TAGs with a replaceable, long-life battery (3 to 5 years). The triggering areas can be configured up to a distance of 50 m.

Examples for TAGs of an RFID system: for drivers (yellow), for pedestrians (gray)

Examples for devices:

Sensor for detection in the danger area around the vehicle/mobile machinery, equipped with LPS technology (LPS = Local Positioning System)

Touchscreen tablet in the driver's cab for configuring all parameters with optional network connection (see next page below)

Portable warning unit/TAG

Features for TAG based Systems

- Multi-level person **and** vehicle detection system
- Configurable safety zones with 6 modelable points
- Detection ranges up to 50m (depending on environment and system))
- Warning of persons **and** vehicles
- Display of the number and position of detected persons in the danger zone
- No optical contact between sensor and TAG is necessary
- Detection is independent of low visibility conditions, e.g. due to obscuring cargo or environmental impacts

- Flexible, fast installation/retrofitting
- Definition of the risk level in real time
- Integration of cameras is possible
- Collection, storage and secure archiving of objective, accurate data captured by the system in the operating environment is possible

Additional protection by integrating an AI camera (optional):

By expanding the LPS TAG system with an AI camera (see image above), both people – wearing a tag and those without a tag – can be recognized.

Recognizing people – even in hidden areas

Image above: The TAG carrying person is detected by the sensor. In addition to an acoustic warning, the driver also gets a quickly interpretable visualization of the situation on his tablet in the driver's cab.

The full-surface expansion of the radio waves of a TAG based system can also detect a person concealed by obstacles.

Depending on the distance within a circular safety zone, the operator/driver and the person(s) in the danger zone are warned automatically – according to specific criteria to be defined.

The radio-based all-round detection works reliably even in poor external visibility, in wet conditions and in heavy dirt – and without blind spots.

LPS TAG system with cloud-based data analysis platform

This technology extends tag-based detection with powerful cloud software that offers real-time analysis of the data collected from the vehicles.
Clear, user-friendly dashboards provide important information directly to those responsible for safety in operations.

The data becomes valuable information that helps to act proactively and minimize risks.

3.5 3D Camera sensors (3D snapshot vision)

Object-specific detection

Object-specific detection makes it possible to reliably distinguish between a curb, a pedestrian or a container, for example.

The technology of 3D camera sensors makes it possible to detect objects three-dimensionally by means of a snapshot. Hazards can be classified in an object-specific manner, their position and volume determined and used in systems with driver assistance tasks.

The following types of camera sensors are used for person/object detection in hazardous areas of mobile machines:

- **3D stereo cameras**
- **3D time of flight sensoren (3D ToF)**

Figure on the right:
Application example
3D stereo camera at the rear
of a construction machine

3D camera sensors warn the operator/driver in critical situations by means of acoustic or optical signals – in addition, the situation is visualized on the monitor in the driver's cab.
The operator/driver can thus concentrate fully on his main task. 3D camera technology has long been used for environment detection and object recognition, for example in port logistics, robotics and assistance systems for passenger cars and commercial vehicles.
In the development of autonomous vehicles, they are considered one of the essential key technologies.

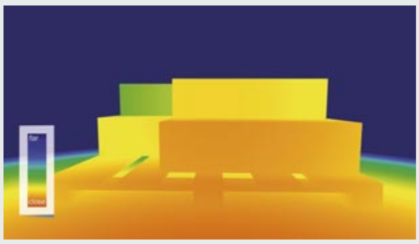
Features for 3D camera sensors (3D snapshot systems)

During procurement, special attention should be paid to the following equipment features, among others, and a specification sheet with the specific on-site requirements should be drawn up beforehand:

- Designed for use in harsh outdoor environments – or even industrial applications.
- Multi-stage distance warning system
- Configurable detection zones to avoid false alarms
- Configurable detection to detect specific objects
- Acoustic and optical warning signal
- Image data recording function
- Stand-alone 3D sensor: intelligent object detection with integrated CMS

perating principle of 3D-Snapshot

3D snapshot means capturing a scene (static or dynamic) three-dimensionally in one shot – without the presence of moving mechanical parts inside the device.

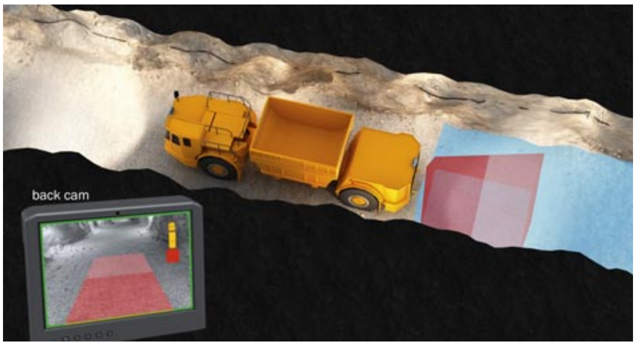


3D snapshot image of a pallet:
The distance of the objects to the sensor is detected and represented by different colouring

▶ 3D camera sensors can be used in wide range of vehicles types, even in harsh environments

3D camera sensors are ideal for driver assistance on heavy, all-terrain mobile machinery used in outdoor applications such as in quarries, mining and construction sites, also in forestry and agriculture.

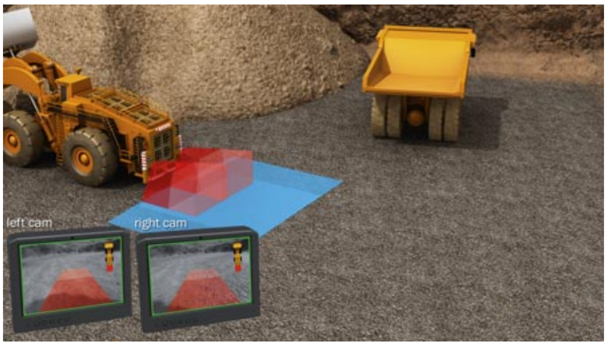
Raw material extraction/mining



For example, used bye following vehicle types:

- Vehicles for tunnels and underground mining
- Heavy duty vehicles
- Excavators

Construction sites

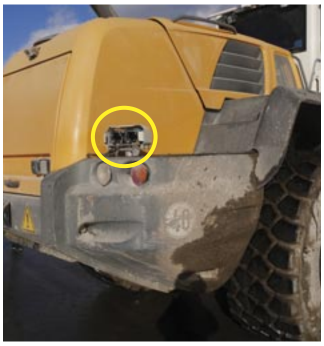


- Wheel loader
- Dump trucks
- Rollers

Agriculture and forestry

Ports and cranes

Due to the large number of different mobile machinery that exist in these fields of work, the requirements for collision warning systems also vary. The 3D camera sensors are therefore available with different technologies and in different versions.



4 Acoustic warning signals

for personen in the vicinity

Warning of persons at risk

In many areas of application of mobile machines, it makes sense that not only the operator/driver is warned of hazardous situations, but also the people who are **in the immediate vicinity**, who walk into the hazardous area (such as work colleagues or passers-by) and who could be in danger without a warning.

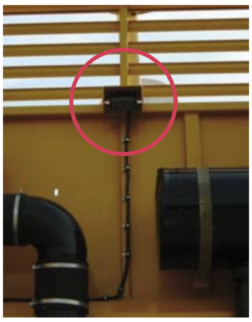
Effectively generate attention

A variety of audible alerts are available to improve the perceptibility of mobile machinery, either:

- are permanently activated when the machine is in motion (e.g. when reversing) or
- are activated situationally, e.g. when a sensor system with intelligent software detects persons/objects (see chapter 5).

The alarm sound generated is perceived as "hissing" or "beeping" and can optionally adapt to the ambient volume. While broadband tone alarms use a directional alarm tone to warn people who are approaching the danger area or are already there, beeps are heard in the entire environment. Therefore, caution is advised!
"Beepers" cause noise nuisances that trigger annoyance and stress among employees and residents. Possible consequence: desensitization to the continuous beeping – an actual threat of danger is no longer assessed as such. Since the beeping sound is difficult to localize, persons at risk must first orient themselves as to the direction from which the danger is imminent.

Photo below: Camera on a construction machinery for monitoring the work area



Depending on the type of work, a combination of CMS and broadband audio warning system may be useful: the driver has a clear view of the work/hazard area and persons at risk are warned acoustically.

Advantages of a broadband tone reversing alarm (white noise)

- Only perceptible in the danger zone (wide frequency spectrum)
- No nuisance due to noise to third parties
- No stress for employees/residents
- No desensitization
- Fast localization
- Can optionally be activated by sensor

Photo on the right: Combination of radar and white noise warning. The radar system signals the driver about persons in the danger zone by an acoustic and visual signal, while the broadband sound warning system alerts persons in the immediate vicinity of the approaching vehicle by a directed acoustic warning.

4.1 Broadband acoustic warning systems

▶ Targeted warning of surroundings – avoid unnecessary noise pollution

Broadband tone alarms represent a new generation of warning systems. They cause less noise nuisance – the iintensive alerting hissing signals are heard where it matters: in the danger zone of the mobile machinery.

For workers, residents and passers-by, there is no (continuous) stress caused by shrill beeps, and the operator/driver is not tempted to switch off the warning system to spare his nerves. There is less risk of desensitization to warning signals.

▶ Quickly detect the direction of the source of danger

Broadband sound frequencies convey directional information to the ear, thus enabling the listener to better localize the sound. This gives time to avoid the danger.

▶ Useable in many sectors and applications

Broadband acoustic warning systems can be used in a wide range of applications, including construction site vehicles and mobile construction machinery, baggage vehicles at airports, trucks, heavy vehicles used in quarries or recycling plants, agricultural and forestry vehicles, and road vehicles.

Different models of broadband sound warning devices are designed according to the wide range of applications.

A quarry environment has to be assessed differently than a vehicle traveling in an inner-city area, for example. The same applies to the requirements for telescopic handlers in enclosed warehouses, barns as well as production environments and for baggage transport vehicles at airports.

Operating principle of broadband noise (white noise)

Broadband noise – also known as "white" noise – is created by the composition of several frequencies. It acts as masking sound in that sound pulses "disappear" in the noise.

By adjusting the sound level ratios accordingly, the listening threshold is set to the required level

Significant for the human perception of the sound produced in this way are the
- spatial limitation and
- fast, perfect localization.

Used as a warning tone, the broadband noise can be adjusted so that the volume adapts to the noise level of the environment.

Broadband sound warner

Technical options:

Among other factors, the noise level in the surrounding area plays a role in selecting the appropriate system. For some applications, it is therefore advisable to automatically adjust the warning tone volume: the warning intensity increases as soon as this is required.

Broadband alarms provide an urgent alert to people in danger. They switch on, for example, as soon as the vehicle starts moving. Other solutions can be configured depending on the model, e.g. when reverse gear is engaged.

For further solutions for warning people at risk in special work areas, see chapter 3.4 TAG based systems (prerequisite: closed premises with entrance control).

5 Person and object recognition

with intelligent software und AI

The possible uses of software, networked systems and AI-based solutions are pushing into practice, being intensively developed and advanced. This applies to both sector-specific and cross-sector solutions for applications in person and object recognition.

While camera/sensor systems, according to their requirement-related specifications, work independently on the same tasks, digitized processes enable further and networking solution paths.
Digital processes can integrate information from multiple sensors.

The measurement data acquired in parallel from, for example, a camera, an ultrasonic sensor and a radar system are evaluated simultaneously. The superimposition of sensor signals increases reliability in the detection of hazardous situations across the multitude of possible environmental scenarios.
The result can be used to trigger a previously defined system intervention – for example, an autonomously induced braking or evasive maneuver to protect detected persons and bring the system back to a safe state.
Digitization provides the basis for simultaneously

- **using AI-algorithms,**
- **making machines "smarter" and safer** as well as an
- **increasing automation of business and work processes**.

Digitization supports value-creating effects through process optimization. It supports and accelerates permanent change. In the process, it brings about new forms of collaboration.

AI definition according to EU AI Act, Art. 3 (1)

- **"AI-system"** means a machine-based system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments;

AI example of use: Detecting accident black spots by data analytics:

- In addition to supporting the driver (see chapter 5.2), accident black spots can also be detected using deep learning.
- For this purpose, the date, time and GPS position of the mobile machine are recorded anonymously each time a potential collision is detected.
- Over a certain time and data volume, "hotspots" can thus be identified and preventive measures, such as improving visibility or braking, can be initiated.

AI (Artificial Intelligence)

Generic term for software programs for simulating cognitive abilities and human intelligence (perception, learning, adaptation, reasoning, action) and for automation.

ML (Machine Learning)

Sub-area of "AI"; algorithms that learn patterns from large amounts of data, optimize themselves and find solutions to a given problem (without the solution path having been explicitly programmed). Example: recognizing objects from trained image data.

Deep Learning (methode of AI)

Subfield of "ML". Deep learning uses "deep" complex, multi-layered neural networks that learn from large amounts of data. Enables, among other things, the classification of detected objects. Example: Characteristic Doppler effects distinguish person from other objects. Doppler effects are perceptible changes in frequency as a passing vehicle approaches or moves away.

5.1 Artificial Intelligence (AI)

Solve tasks quickly, error-free and automatically

Artificial intelligence (AI) is a branch of computer science, deals with the simulation of human intelligence and cognitive abilities (competence to perceive and recognize information from the environment) to enable “intelligent” behaviour in machines and vehicles.

Using a large amount of data, AI enables machines to **make plausible decisions quickly and automatically**. In order to act autonomously, algorithms process and analyze the experiences made by the system, can remember them and **learn from trial and error**. The system can **train based on detected errors, develop itself further and improve**.

The goal for a respective AI is the ability for the machine to react to all possible challenges in its field of action, to behave "intelligently".

AI-based control systems can interact with their environment and make decisions largely independently. In an emergency, for example, **they must reliably recognize a person at risk and initiate protective measures such as braking**.

Here we are entering new legal territory in terms of operational safety when it comes to **evaluating the framework conditions of AI systems**.

In general, an AI system is trained during the training phase, e.g. using machine learning.
In the operating phase, i.e. when the machine is in use, no further autonomization takes place.

Neural networks

Whereas in classical programming, manually created instructions enable control structures and deliberately incorporate them, an AI system replaces the manually created programming sections with self-learned neural network structures.

Neural networks represent one of the most powerful families of algorithms in AI. They learn complex relationships from training data that are not readily comprehensible to humans. Neural networks can recognize patterns and can be improved by collecting data during operation in a subsequent training phase. A special case is the use of several networks that improve each other in this training phase.
An AI system is equipped with the respective sensors that are assumed to be able to collect the required data for further processing and learning.

One particular application of AI that is relevant to person and object recognition is what is known as Machine Vision or Vision AI.

Machine vision captures and analyzes visual information using 2D and 3D cameras and is often compared to human vision, as it virtually enables a machine to see.
The aim is to be able to use the visual information captured in this way to draw conclusions.

AI systems depend on their data

For learning, AI systems use extensive data (see page 33) from various sources:

- the **master data** (the already existing, grown data),
- the **metadata** (containing information about data from other sources) and
- the **new data** generated in the AI system deployment.

Data transprency:
Providers of safety-relevant AI systems (see chapter 5.1.1) are obliged to make the sources of their data transparent.
It is therefore no longer permitted to use pre-trained, publicly available AI models as a basis.

5.1.1 Safe and certifiable AI

A safe AI based system requires not only a safe AI model but also hardware and software development that keeps safety in mind.

AI algorithms process large amounts of data, connect them, and draw defined conclusions from them. Although the goals for data input and output are known, the processing steps within the system often cannot be explained because they take place hidden in a **black box**. The user receives a solution but does not know how it was achieved.

The goal is the **white box**, an explainable approach. Nevertheless, that is up to now quite limited and a large field of research.

For active assistance systems that intervene in vehicle acceleration or braking, as well as for the automation of work processes in machines and guided vehicles, AI is increasingly taking on a central role.
Traditional approaches to qualifying decisions face the problem that AI solutions are not based on transparent algorithms but rather on the incorporation of millions of parameters determined through a training process.

This makes AI difficult to predict (Black Box approach). To qualify reliably, approaches must be found that allow for statistical assessments of AI behavior.

In addition to the EU AI Act (Artificial Intelligence Law – Regulation (EU) 2024/2689), the first standards emerge that describe the use of secure AI.
From those, six key quality criteria can be derived:

Quality criteria for a secure AI (Excerpt according to Article 10 of the AI Act, Use of High-Risk Systems)

1. Fairness & Bias

The results of the AI model must be based on fair and unbiased decision-making. This requires an evenly distributed representation of the intended use case in the training dataset (e.g., gender, age, nationality).

2. Transparency & Explainability

Transparency must ensure that a decision (e.g., a recognized person) is based on features that define a person (such as head, arms, and legs) and not, for example, on the color of their clothing.

3. Data Management & Quality

The performance of an AI model is defined by the training data used. This results in high-quality requirements for the collected data to cover the use cases and customer requirements. Additionally, data containing personal information must be handled in compliance with the GDPR.

4. Reliability & Safety

The AI development process needs to follow a defined procedure (MLOps = Machine Learning Operations, see text below) Additionally, the operation of the AI system must be carried out on reliable and uninterrupted hardware and software.

5. Performance & Functionality

AI system must achieve the defined recognition rates under the specified conditions set for this particular use case.

6. Robustness & Security

All steps of model creation must be protected against cyber-attacks. Furthermore, the AI must be designed to be as robust as possible in order to handle, among other things, intentional deceptions.

MLOps
(Machine Learning Operations) is a core function of Machine Learning Engineering.
It focuses on the process steps required from AI training to transitioning into production.

Consideration of a complete system

Meeting the AI quality criteria requires, in addition to high organizational requirements, such as the implementation of certain processes, a quality management system including a high level of documentation, significant effort for validation. Through defined test datasets, which should comprehensively and accurately describe the parameter space of the intended use of the AI, proof can be achieved.

Figure on the right: SAFE AI Ethernet camera with extensive hardware and software safety features, as well as a safe AI model.

For the qualification of an AI camera and ultimately its certification, the entire system, consisting of the AI model, hardware, and software, must be considered. No danger must arise from this. It must be ensured that both the function of the AI model and the communication with the vehicle are functionally safe.

Which data are relevant?

For training machine learning models, we need training, validation and test data.

- **Training data**
  are used to adjust the network's weight.

- **Validation data**
  This dataset is used to measure the already achieved performance and ideally identify any remaining weaknesses (e.g., kneeling persons are not recognized with high confidence). In the next training run, further training can focus on these features (also referred to as corner cases) until the network has overall achieved high confidence (Additional information can be found in the right column).

- **Test data**
  is used after the training for verification. They serve the external, independent testing of the neural network and typically come from the customer or a certification body. The algorithm does not know these data.

What amount of data is needed?

The amount of data depends on several parameters and the heterogeneity of the use case.

With each parameter, the number increases by one dimension and quickly reaches over a million.
Taking the example of person detection, it quickly becomes clear that even for a small subset of the conceivable parameters, such as viewing angle, rotation, occlusion, pose, gender, clothing, and environmental conditions like light, rain, snow, etc., hundreds of thousands of images are required. With each additional parameter, the number of possible combinations increases by one dimension.

Since it will be difficult in practice to cover all combinations of the parameter space, synthetic data is increasingly used, which, thanks to modern rendering software, can already come very close to real data.

At least for validation or testing, synthetic data is suitable, and it can be proven that the so-called 'reality gap' (the gap between images from the real world and synthetic images) is very small.

The validation dataset must represent the so-called ODD (Operational Design Domain) evenly to ensure that the training process leads to a meaningful result. During training, these data are used, among other things, to determine whether the AI model improves over the training epochs.

5.2 Personen and object detection using artificial intelligence (AI)

Camera-based collision warning

360° all-round vision system with object recognition by learned neural networks:

System components: Ethernet cameras, computer unit and touch monitor (7"- or 10")

The camera systems with integrated collision warning are based on the application of artificial intelligence. With the help of so-called artificial neural networks, a wide variety of objects are recognized and classified by camera images.
Neural networks learn to identify certain object classes by their appearance through a large number of sample images. These can be, for example, persons and objects in the area of a construction machine. The number of examples required to teach/train the system depends on the desired application. With this corresponding number of sample images, persons and objects in other industries and applications can also be recorded.
The trained neural network can thus recognize static and dynamic objects in the camera image in real time and determine their position (examples of system components, see figure on the left).

Classification at CMS

The driver receives specific acoustic and/or visual warnings for persons or objects that are particularly at risk.

To minimize the rate of unnecessary false alarms, however, the driver is not warned about untrained object classes, such as signs and other static objects.

In combination with a computing unit and implemented application software (neural network), a CMS can become an active safety support for the driver.
The KMS recognizes the classified objects and persons in the camera image section – see figure on the right and in the left column.

Figure above – Example of use: person detection:
The camera positions mounted on the wheel loader and thus known are used to provide a sufficiently accurate distance estimate that makes a timely warning possible. The prerequisite for this is a one-time calibration process when the cameras are mounted.

Application example above:
The AI system installed on a rear ripper recognizes the pedestrian, classifies them as a person and warns the driver of an impending collision.

Visual warning zones can be defined to determine when the system should detect objects and people and alert the driver. These can be flexibly and individually configured.

The system can be "taught" or "trained" to recognize further new object classes on a case-by-case basis, meaning that the solution can be used in many different industries and sectors.

In combination with radar/ultrasonic sensors or stereo camera technologies, further improvements can be achieved for detecting objects or people.

Security with deep learning technology

Camera-based collision warning using embedded AI is finding an ever-increasing range of applications in various mobile machines and commercial vehicles in different areas and environments.

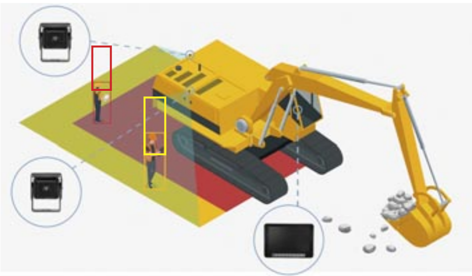
Wherever people/objects are involved in dynamic processes, there is a particularly high risk of danger. In addition to classifying and determining the position of detected objects, the embedded AI can also calculate motion sequences and anticipate impending collisions.

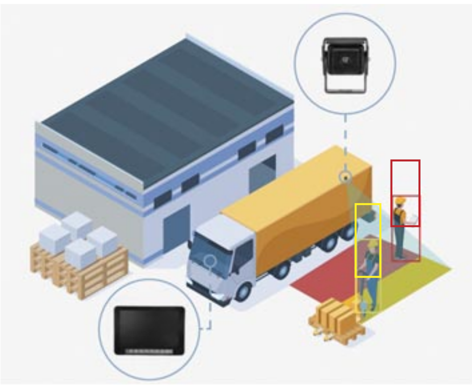
Intelligent motion recognition

Images from camera sensors are evaluated by the AI, which has been specially developed using deep learning processes and the future course of movement of the endangered objects is calculated.
At the same time, the direction of movement of the driver's own vehicle is also determined. If the two vectors/lines of movement overlap, the system warns the driver of the risk of collision.

Depending on the system and application, the AI software can be applied directly to the sensor or to an intermediate control box.

Top image: Intelligent camera as an example of an Ethernet camera with person/object recognition that runs directly on the camera without additional hardware.





Images above: smart person recognition using AI cameras in a range of applications and vehicles.

Extended detection range

The camera's detection range can be significantly extended by an integrated AI. This means that objects and people can also be detected to the side of the front of the vehicle and even in the second row, such as behind parked cars.

Example of use in a wheel loader:
The robust camera delivers HD images of critical areas such as the rear area, etc.
(see photo above).
The CMS is equipped with object recognition
(see graphic below).
The warnings can be issued in a variety of ways depending on customer requirements.

Advanced system properties

- AI-based camera systems also work in limited lighting conditions,
- can be used for different vehicle types and are easy to install,
- can be easily updated with software updates.
- The use of the vehicle's CAN signals and
- customizing of the system are possible.

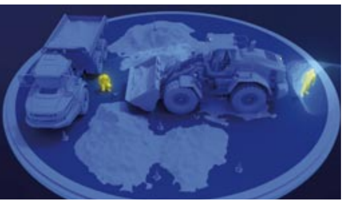
AI cameras are used in a wide range of applications – even in harsh environments such as quarries or construction sites (left image).

5.3 Example of AI solutions to improve industrial safety and productivity

System main components:

Sensor, smart color display and flash beacon

Two systems are mounted on the wheel loader (front and rear). These detect and localize people in real time and alert the driver in case of danger without unnecessary alarms.



AI-powered connected pedestrian detection to prevent collisions with mobile heavy equipment

Vehicles and mobile machinery that regularly operate near pedestrians pose a high risk of collision, which continues to be the cause of many accidents. The driver has poor visibility due to the vehicle's load and blind spots.

The compact, robust system example is easy to install. The AI camera detects and localizes people in real time and in any posture (standing, crouching, in partial view) to prevent collisions with vehicles such as wheel loaders, dumpers, excavators.
An LCD color display or a Flash Beacon alerts the driver through visual and audible alarms when a person is detected in the defined danger zone, at the rear as well as at the front of the vehicles. Using AI, the system distinguishes people from obstacles and only triggers relevant alarms.
False alarms are avoided, which leads to high driver acceptance.

Top image: The sensor looks after the area within its field of view – including the wheel loader's blind spots – and detects every body posture.

What the driver sees:
A lot of blind spots!

What the system sees and alerts:
The crouching pedestrian.

Automatic speed limitation in risk areas

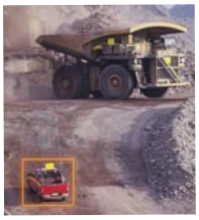
This solution enables the automatic limitation of the speed of vehicles entering risk areas, such as areas with high vehicle/pedestrian co-activity, narrow aisles, dangerous intersections, doors, etc.

Right image:
Example of an automatic speed limitation on a wheel loader

Vehicle collision avoidance

The solution goes beyond pedestrian detection: it detects and localizes not only people but also other vehicles in the area, thus guaranteeing more comprehensive collision avoidance.
A high level of productivity is maintained and operations are not interrupted by accidents.

The system detects and localizes other machines to avoid collisions with them.



Safety & productivity analytics

The integrated cloud-based IoT (Internet of Things) fleet management solution helps operations improve productivity and significantly increase the safety of people near machines. The risk of accidents can be reduced by a factor of 3.
Thanks to GPS and 4G connections, a dashboard provides access to relevant metrics, photos and hotspot mapping to make data-driven decisions. For example, it shows the most dangerous vehicles and determines when and where the risk of accidents is highest.
Companies can prioritize, take proactive actions on their organization and measure their efficiency.

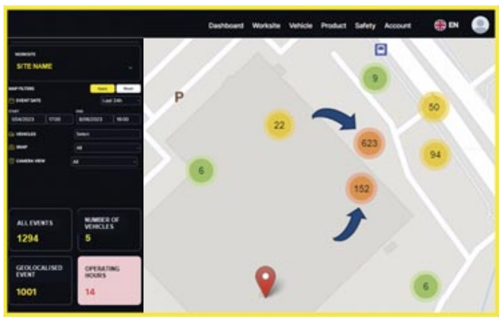
The connected solution provides access to relevant dashboard metrics/KPIs and hotspot mapping to monitor the vehicle fleet and improve site safety and productivity.

Overview and control of relevant risk factors:

The IoT solution reduces the risk of accidents by a factor of 3. (Result at the deployment sites.)

The dashboard provides access to relevant data and identification of the most dangerous vehicles, locations and times with the highest accident risk.

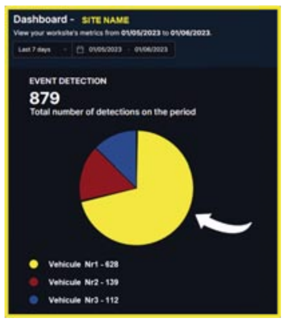
At a glance, identify where you have the highest risk of accidents on your sites.



Visualize the direct impact of your actions on site to reduce pedestrian-vehicle co-activity.

Find out when the risk of accidents is at its peak for each site.

Pedestrian detection shows which machine is the most dangerous.



5.4 Aktive person detection with brake assistant when reversing (wheel loader)

The next step towards even greater safety in the use of large mobile machines is the development of active brake intervention for earth-moving machines.

Even with an active assistance system, the driver is still responsible!

Therefore, increased attention is essential when reversing/maneuvering, even with an assistance system.

Despite being equipped with a CMS, serious to fatal accidents occur when using mobile machinery. Particularly when reversing large earth-moving machines, there is an increased potential hazard.

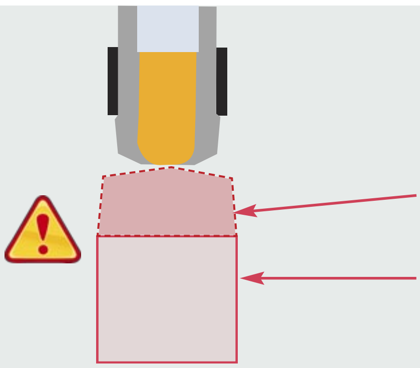
The warning provided by sensor systems described in chapter 3 offers additional safety, but still requires active action by the driver/operator. Mistakes can happen even with great care and experience.

An active assistance system - which functions independently of human response – can provide even more effective protection in the event of field of vision impairment. The system comprises a

combination of	camera sensor technology + data evaluation + reduction of speed

▶ If there is a risk of collision, the wheel loader decelerates automatically

Image above: Illustration of the person detection system in the rear area of the wheel loader, which triggers both the warning to the driver and the automatic braking of the machine; plus illustration of the display on the monitor in the driver's cab (small image on the bottom right).



Picture on the left: The warning to the driver and the reduction of speed take place when:

- **persons or objects are up to approx. 2.5 m**
- **persons are approx. 2.5 m to approx. 6 m**

behind the wheel loader.

The active person detection monitors the rear area of the wheel loader and warns the driver of impending collisions. The intelligent sensor system distinguishes between people and objects: **If persons are detected in the rear maneuvering area, the system alerts the driver earlier than in the case of objects.** (Avoiding unnecessary warning signals.)

The brake assistant automatically reduces the wheel loader's speed to a standstill as soon as a source of danger is detected. **Braking is initiated earlier and faster than conventional braking – as human reaction time is eliminated.**

Technical options:
The active rear personal recognition system plus brake assist can also be combined as an option, e.g. with

- a front camera to monitor the front working area or
- a 360-degree system for bird's-eye view of the entire working environment and/or
- an adaptive working light for working in the dark.

5.5 3D terrain mapping (3DTM)

Intelligent software for terrain and object recognition

Functions based on 3D terrain mapping provide an important building block for supporting the driver and preventing accidents. 3DTM represents an innovative method for terrain and object recognition (e.g. vehicles, living beings, obstacles). It now paves the way for active assistance systems in the off-road sector/NRMM as well.

Terrain detection - 3D terrain mapping (3DTM)
To compute a 3D terrain map, an elevation map is generated based on a grid structure.
In successive calculation steps (spline approximation), the terrain is modelled so precisely that it represents reality. In addition to environmental information such as the presence of hills, slopes, etc., finer terrain details are preserved.

Object detection – generic object detection (GOD)
On the modelled terrain, the slope information is used to determine the trafficability. In addition, the terrain map is used to identify obstacles: With the help of algorithms, objects are detected and their distance to the mobile machine is calculated, as well as the direction of movement and the speed of the objects are determined.

Innovative image processing supports safe working

Based on sensor information – such as that from a digital camera or lidar – people, objects, obstacles and even the most difficult terrain are detected automatically, enabling the driver and the mobile machine to derive clear information. If necessary, the fusion of different sensors or sensor technologies is also possible. The driver is informed by a real-time display on the monitor about the specific conditions, such as:

- where is the terrain passable/not passable?
- what obstacles are located where and at what distance from the mobile working machine?
- in which direction are people and/or objects moving?

Exact terrain and object classification
By applying deep learning methods, the system trains and learns, among other things, how to safely distinguish between people and objects. The targeted training in the specific working environment of the mobile machine (e.g. quarry) enables a very accurate interpretation of the delivered data and thus increases safety and efficiency.

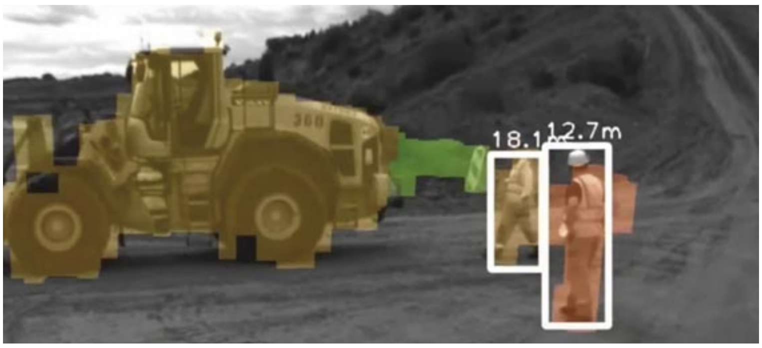


Image above: Clear color scheme and exact distance information enable the situation to be quickly detected.

Depending on the application, the image data supplied can be combined/configured with existing systems or new systems to be integrated, and precisely fitting "actions" can be defined. If there is an imminent danger of collision, for example:

- the driver is additionally alerted by e.g. an acoustic signal and/or additionally
- persons entering the danger zone are warned by a directional broadband tone.
- If the legal framework permits, active intervention in the machine control system – such as automatic braking/evasive maneuvers – can also be triggered.

5.6 Opportunities of digitalization for occupational safety for mobile machinery and stationary equipment

Practical example of safety protection device for dragline systems of concrete mixing plants

For further informationen DEQ see page 46.

With the aim of digitizing quarry processes and thus making them more efficient, safer and environmentally friendly, 25 cooperation partners are working together in the EU-funded project **DigiEcoQuarry** ((DEQ for short). One central question is:

Photo above: Dragline system of a concrete mixing plant during operation.

How to reduce the number of hazardous situations?

Currently, dragline systems (see photo on the left) of concrete mixing plants are being considered in particular.

In the development of dragline systems, cabins were originally used for control, in which the machine operator sits during operation and controls the system. This allowed him to see the scraper bucket and also monitor the main danger area of the plant. In this way, the machine operator had the possibility to stop the plant immediately in case of a hazardous situation (e.g. person takes samples from a box).

Automation processes in the raw materials industry require new safety concepts

Then the plants became increasingly automated. In automatic mode, the bulk material is dumped from the truck as close as possible to the foot of the respective bunker. The scraper transports it upwards fully automatically. There is no longer any need for a machine operator to sit in the cabin. Controlling of the hazardous area now only takes place from a random basis, e.g. by briefly looking at a monitor in the machine operator's room – without a direct view of the bucket.

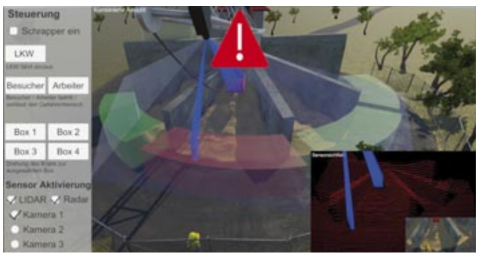
The use of a **functionally safe system** (see also page 7), which detects hazardous machine movements by using appropriate sensors and triggers a safe stop could thus give plant operators more legal assurance.

Objective

However, there is currently no solution available on the market for this purpose. Developing such one, including all relevant parameters, is one of DEQ's intended goals.

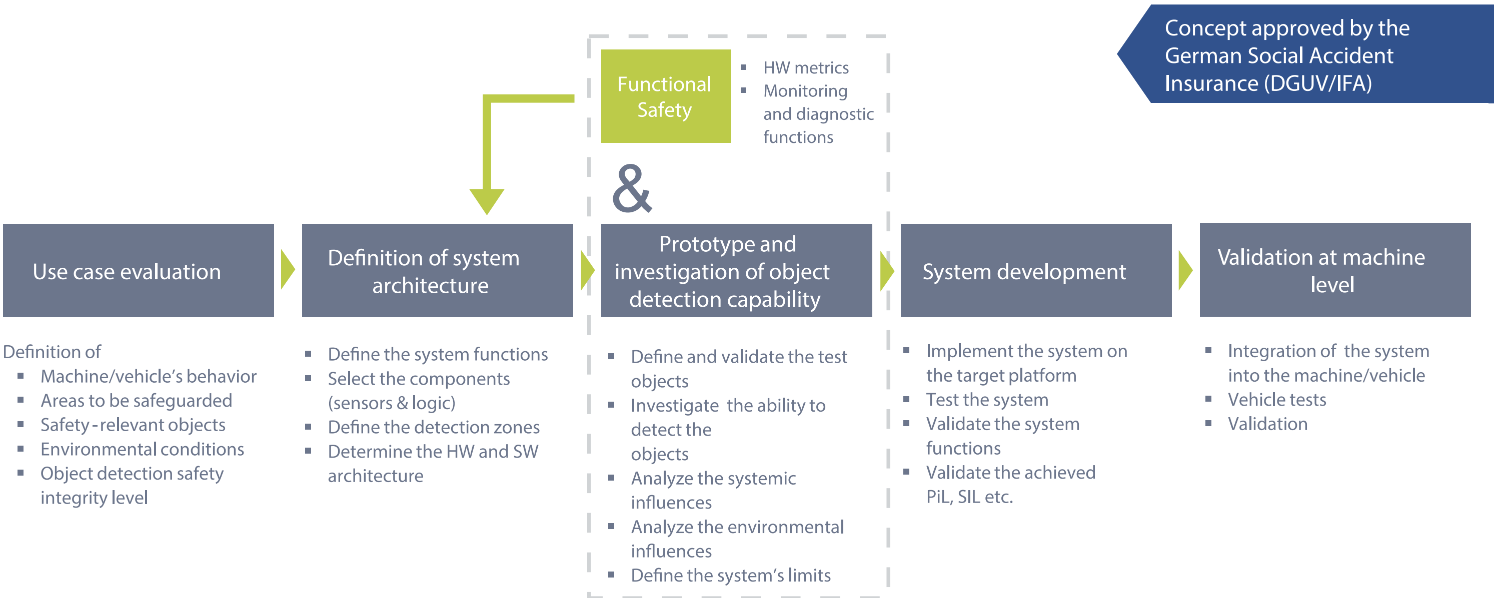
The development process shown integrates various internal and external stakeholders from the beginning.

The development process described below has become established for such kind of applications.



Visualization of hazard risks detected by various sensor data.

Safeguarding human-machine interaction – development of intelligent algorithms for reliable sensors



Step 1: Analysis of the use cases

In the first step, together with operators and the Employer's Liability Insurance Association Raw Materials and Chemical Industry (BG RCI), the relevant use cases are analyzed and defined, also with regard to occupational health and safety requirements. The main focus is to identify and understand the system, its capabilities and limitations, as well as any hazards and associated risks.

There are many requirements which have to be met, depending on the use case. Examples include among others, dust, wind wheather, difficult light conditions, different types of vehicles/machines, open terrain or 24/7 operation – must be taken into account as parameters in the development of the system.

This approach saves a great amount of time and effort, since, for example, the time-consuming assembly of prototypes on the cantilever is no longer necessary.

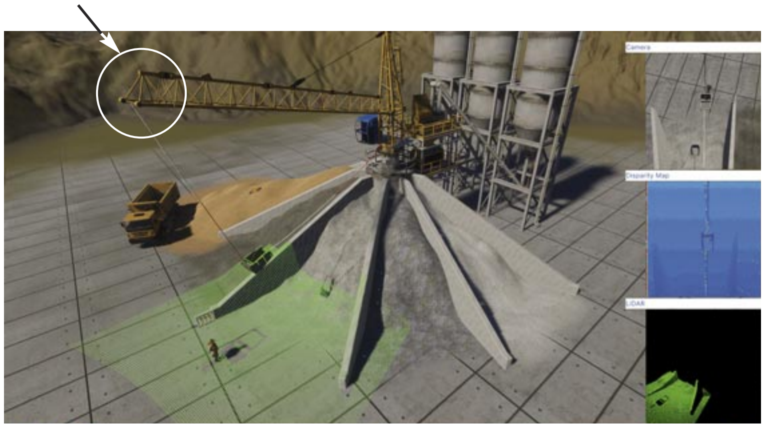


Figure above: "Digital Twin" simulation of a of a dragline system with visualization of camera/sensor data

Step 2: System design and simulation

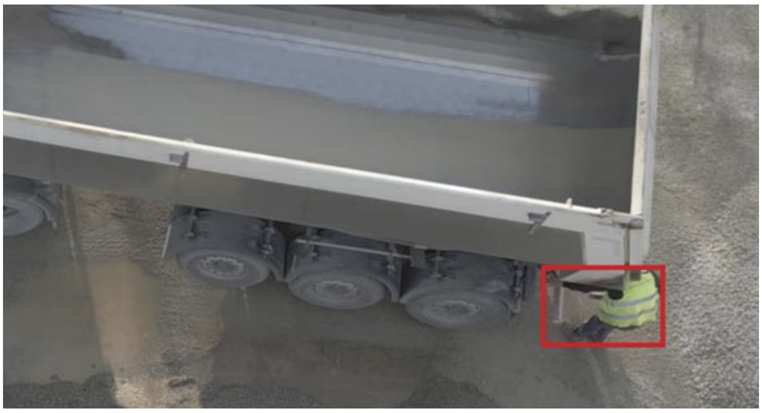
The next step is to make decisions regarding the required architecture and system design in order to be able to select the right sensors.

Here, the use of a simulation environment ("Digital Twin", s. Fig. right) can provide helpful initial indications of which sensor types are suitable for the specific use case (also taking into account the various environmental conditions).

Step 3: Development of prototype

Currently, the prototypes will now be tested on real plants and further developed so that, by the end of the project at the latest, significantly improved accident protection can be achieved in all concrete mixing plants.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003750).

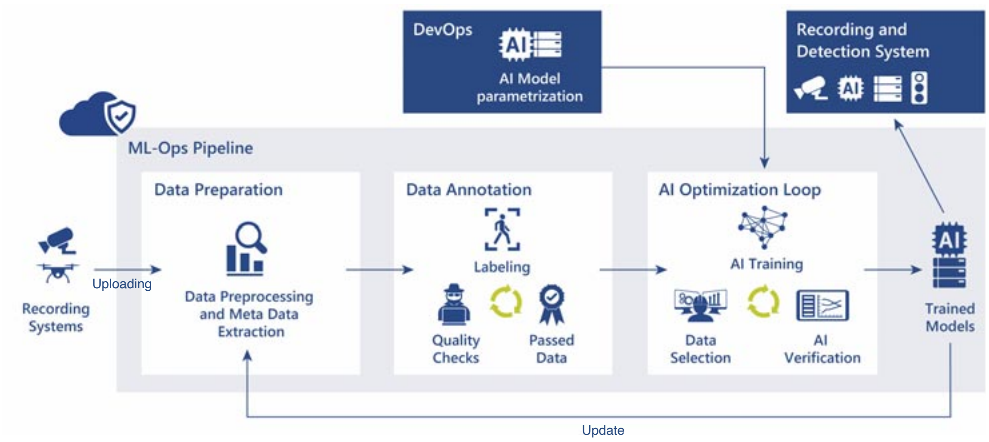


Thanks to the latest AI technologies, the algorithm can even recognize difficult situations, for example, those in which people are partially obscured by other objects (see photo above).

During the system design phase and later in prototype development, it became apparent that to ensure the high system availability required by operators, the use of Artificial Intelligence (AI) in conjunction with a camera system is beneficial, because:

- The conditions at the different plants (such as bulk material in front of the bunkers) require object classification.
- AI-based classification algorithms are significantly more performant than classical algorithms.

The development of functionally safe AI applications presents a particular challenge because AI models, especially deep learning models, are characterized by an inherent black-box nature.
Unlike traditional, rule-based systems, whose behavior is determined by explicitly programmed rules and can therefore be understood, AI models learn implicitly from data. This implicit knowledge representation makes it difficult to predict system behavior in unknown situations and to identify potential errors or vulnerabilities.
To at least partially mitigate these challenges, an AI pipeline specifically designed for object detection is used. Equipped with the right tools, an AI pipeline is a structured and automated workflow that encompasses the various phases of AI development, from data preparation and annotation to model training and evaluation, and finally deployment – see graphic:



Outlook:
Successful tests at multiple plants indicate that the current approach is promising. In further steps, the system must be validated.

This workflow increases transparency and traceability in the development process. By automating and standardizing the individual steps, the entire AI development cycle is documented and traceable, enabling more precise analysis of model behavior and the identification of potential vulnerabilities.
The iterative nature of the pipeline, facilitated by the AI optimization loop, also allows for continuous model improvements based on new data and insights. The integration of simulation environments and virtual tests further allows the evaluation of system behavior in critical scenarios that would be difficult to reproduce in reality.

In this way, the safety of the AI application can be increased through the systematic consideration of critical scenarios and the continuous improvement of the model, strengthening confidence in the system's reliability.

5.7 Automation software for construction machinery

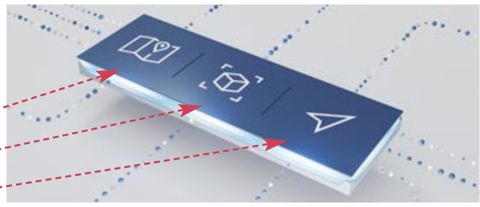
Support for machine manufacturers

Thanks to a newly developed software platform, mobile machinery can now be automated quickly, easily, and efficiently. The new software concept for the field of automation simplifies the development of assistance and autonomy functions for mobile machinery, to the benefit of small, medium-sized, and large manufacturers alike. By accessing this platform, machine manufacturers can focus on the core aspects of their development work, while large parts of the autonomy functions are delivered via the platform provider.

Modular software platform for quick and easy development

The software platform features a modular design and includes three main elements

- **Localization and mapping**
- **Obstacle detection**
- **Path calculation (navigation)**

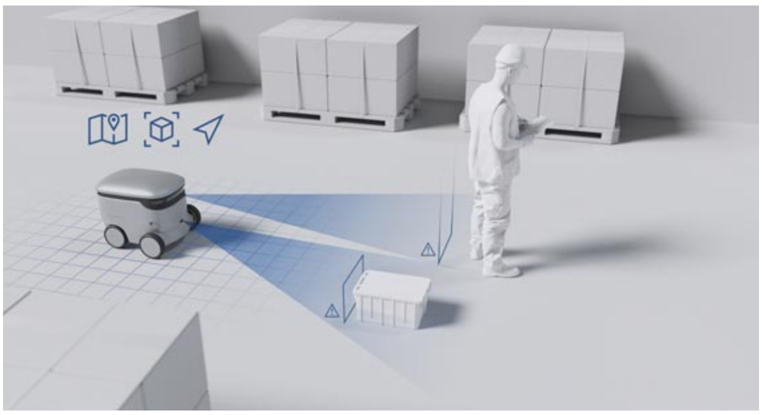


These main elements represent all core functions for complete machine automation. The software modules can be integrated into the machine's control software either individually or as a harmonized package.
The software platform is based on extensive experience gained through our engineering work for the automotive sector as well as dedicated research and advance engineering for off-highway applications. As a result, the software is characterized by its extremely precise and efficient perception of the surroundings along with reliable signal evaluation and smart navigation functions.
The behavior of the machine and its interaction with the surroundings can be individually defined. The various parameters of the automation software can be flexibly adapted to the specific requirements of the respective application. Depending on the work process, the machine can, for example, stop in front of obstacles and wait for clearance from an operator, or can avoid obstacles before returning to the originally calculated path.

Figure below:
The robot navigates automatically, detects obstacles on its path, and avoids collisions with these objects.

Software also ensures great flexibility for hardware concept

Depending on the specific operating conditions, the following can be integrated into the system:
1.) Radar sensors
2.) Ultrasonic sensors
3.) GNSS receivers for global navigation satellite systems
4.) Lidar and
5.) other Sensors
Standardized interfaces based on the robot operating system 2 (ROS 2) facilitate the integration of the software modules into the machine's software architecture.



5.8 Intelligent video analytics for personal protective equipment (PPE) detection

▶ Reliable detection of correct PPE use to comply with occupational health and safety regulations

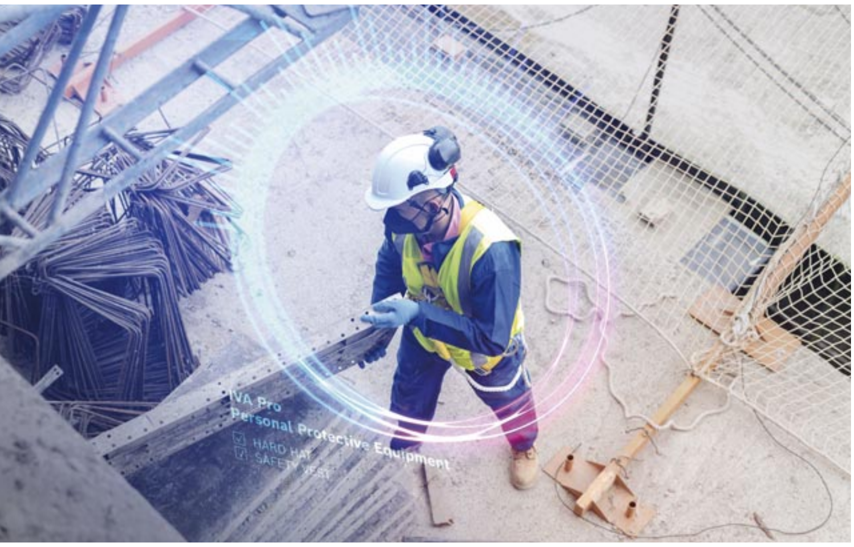
A software-based solution can be used to automatically ensure that people are using personal protective equipment (PPE) correctly. Using intelligent video analytics, it not only reliably detects whether PPE items such as hard hats and high-visibility vests are missing, but also immediately alerts users if they are not in compliance.
This enables companies to comply with safety regulations, minimize the risk of accidents and increase operational efficiency.

▶ The special challenge for companies

Many companies and facilities are subject to strict safety regulations that require the wearing of personal protective equipment.

Failure to wear PPE increases the risk of work-place accidents and can lead to downtime and fines.

Organizations are therefore faced with the challenge of efficiently and reliably monitoring the use of PPE in order to keep people safe and minimize financial risks.



Intelligent Video Analytics for Personal Protective Equipment (PPE) Detection

▶ AI safety solution for efficient support

However, manual monitoring of PPE is time-consuming, labor-intensive and error-prone.

▶ **Intelligent software-based analysis of video streams allows this effort to be fully automated in compliance with GDPR (General Data Protection Regulation).**

▶ **The required detection zones, time periods and alarm criteria are individually defined.**

If a person is detected without personal protective equipment such as a vest or helmet, an alarm is immediately triggered and, for example, security personnel are notified so that action can be taken quickly.

Safety for companies, employees and external parties:

Although it is in their own interest to do so, people who find themselves in an environment with a high accident risk are often not fully aware of the fact that they are exposing themselves to an avoidable risk potential due to inadequate visibility and/or unprotected body parts.

Intelligent video analytics for detection of PPE offers many benefits to companies:

- **Improved safety compliance:**
  Automated monitoring and real-time alerting of violations ensure compliance with applicable safety regulations and minimize the risk of fines.

- **Increased operational efficiency:**
  Eliminates the need for manual PPE fit checks, saving human resources and increasing the efficiency of safety monitoring.

- **Reduced accident risk:**
  Consistent PPE wear monitoring reduces the risk of workplace accidents and injuries, increasing workplace safety and minimizing associated costs.

- **Deeper scene understanding:**
  The video solution's intelligent software provides valuable metadata describing the content of the scene being analyzed, enabling a more complete understanding of the situation.

The company's specific requirements define the relevant alarm criteria:

AI video analytics is based on algorithms specifically trained to detect different types of PPE and/or defined situations. The required parameters are precisely determined according to the operating and environmental conditions.

Intelligent video analytics works reliably whether people are standing, walking or bending over.
It can also be used in difficult environments, such as silos, quarries, and other scenarios:

- Detection of people without PPE entering a zone
- Detection of persons and vehicles in defined zones
- Detection of line crossings
- Detection of people following a route
- Detection of people loitering
- Counting people and vehicles

In the area of personal identification with personal protective equipment, new requirements are defined by operators and professional associations.
This leads to improvements in occupational safety. Regulations and standards such as the Occupational Health and Safety Law and the Industrial Safety Regulations support operators in using video technology to minimize the incidence of accidents and injuries.

European project DigiEcoQuarry (DEQ)

DEQ covers the quarry as a whole, from small up to multi-site quarries, and includes 8 processes

The project will have a positive impact on the environment, social issues, health and safety at work, and profitability in relation to quarries, and will contribute to the expansion and strengthening of the aggregates industry in the EU.

https://digiecoquarry.eu/

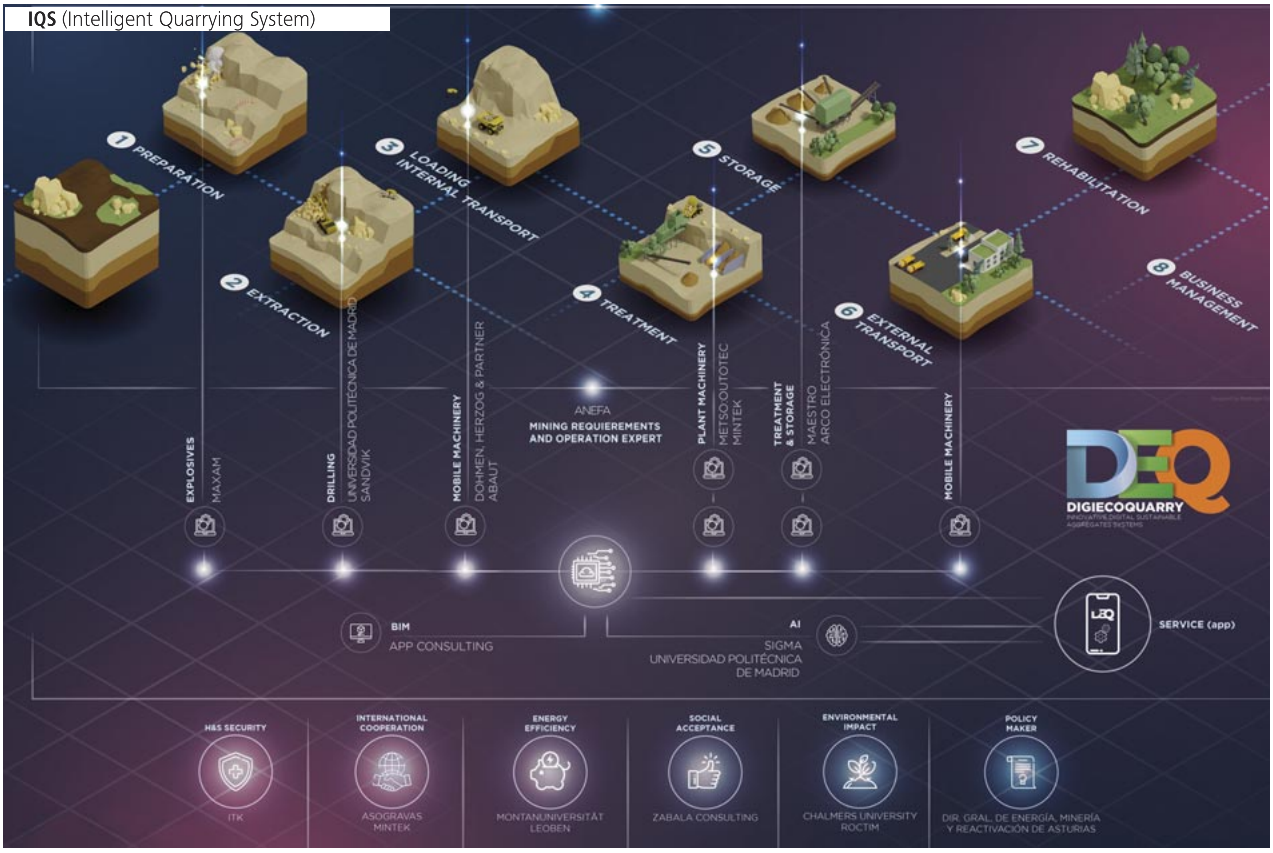
The figure below shows the general logic of the collaboration between the partners and the performance of data collection throughout the entire mining operation.

The **network of IoT sensors** collects data about machines, materials, the environment and other important parameters on site. Sensor data is collected by on-site sub-platforms and a cloud-based main platform, the **IoT Smart Mining platform**. This interoperability platform provides the necessary interfaces for receiving heterogeneous data and offers data storage capacity (data lake) for each location.

The main platform thus enables the standardized exchange of all relevant data with BIM and the sub-platforms (the latter are implemented as a data warehouse including the AI processes and algorithms). These sensors, sub-platforms, the smart IOT platform, BIM models, AI components and services together constitute the Intelligent Quarrying System (IQS).

The IQS will ensure that the entire quarry management is optimized from a global and holistic perspective in quasi-real time by defining priorities between process interactions, resulting in a decision-making framework.
This ensures a market potential and competitive advantage gained through the pilot sites and leads to a business model that can be implemented and replicated across the EU and worldwide in the coming years.

IQS (Intelligent Quarrying System)



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Take advantage of our demonstration possibilities of the different systems at your events such as in-house exhibitions, training events, congresses...
Contact us directly: info@safety-machinery.com

Collision avoidance for mobile machinery and commercial vehicles

Person/object detection, warning in hazardous areas

Camera, sensor systems, intelligent software for mobile machinery:

» Construction machinery; and special edition for the mining industry
» Tractors and mobile machines in agriculture and forestry
» Forklifts and industrial/conveyor trucks

▶ Guides for operators, manufacturers and supervisors

Coming soon: **Collision avoidance assistance systems**
for heavy commercial vehicles and buses

Turning/assistance systems

» For heavy commercial vehicles, buses and mobile machines
» Trucks, municipal vehicles, agricultural and forestry vehicles

▶ Guidelines for operators, manufacturers and supervisors

Camera monitor systems – useful and safe retrofitting

Tips for installing camera monitor systems

▶ Guide for companies, specialist dealers and installation workshops

Professionals take care

Recognizing and avoiding hazards due to restricted vision

▶ Practical help for employers, employees and interest groups

Using earth-moving machinery economically and safely

Knowing measures – working productively – profiting

▶ Practical guide for operators, contractors and managers

Functional safety for mobile machinery and vehicles

Safety and industrial security in the development and use of control systems

▶ Information for operators, manufacturers and supervisors

6 General principles

for procurement and operation

When configuring a system, always follow the respective manufacturer's instructions and hire a specialist company to do the work!

Potential and limits of technical aids

If direct vision of the driver is not sufficient to ensure safety, technical means or technical measures (cf. TRBS 2111 Part 1, Clause 3.2.1 Para. 3 and 4 – see p. 45) must be used primarily to improve visibility, such as camera monitor systems (CMS).

Camera technologies, warning and sensor systems are technical aids for detecting persons and objects in the danger zone of mobile machinery and commercial vehicles.
These systems support the monitoring of the working and movement area of the mobile machines in case of machine movements and if necessary also in case of movement of attachment components.
Extended systems can additionally warn persons in the danger area.

CAUTION:

- Warning systems are not intended to perform driving movements without visibility!
- The systems are intended in particular for monitoring the danger area around a machine.
- Displays, camera images, warning signals must remain clear and manageable for the driver – so that imminent hazards can be recognized immediately.

Operational readiness

Warning and sensor systems, as well as a camera monitor system, must function properly when the mobile machine is started.
A functional check is therefore mandatory before starting work.

Retrofitting: Selecting, mounting and aligning mounting points

Determining the optimum mounting location and the correct alignment of the camera, sensor and monitor/display for the application depend on several factors, for example:

- the location, the operating conditions, the resulting necessary detection range of endangered persons and objects,
- the design and ergonomic requirements of the machine.

For more information, see the guide "Camera monitor systems – sensible and safe retrofitting" (www.safety-machinery.com).

Signalman (spotter)

As long as no sufficient view is possible (neither directly, nor by means of technical measures such as mirrors, CMS, sensor technology), temporary signalman are required!
Only if the use of suitable equipment, such as CMS or sensor systems, ensures unrestricted monitoring of the route, a guide may no longer be required. Technical measures have priority – the traffic guide is the exception!
If you have any questions, contact your employers' liability insurance association or accident insurance fund!

Inspections by a "person qualified to inspect"

The "person qualified for testing" in the sense of the Ordinance on Industrial Safety and Health (German §2 (6) BetrSichV) is someone who has the necessary specialist knowledge for testing work equipment due to his professional training, professional experience and recent professional activity.

The subsequent installation of a CMS, warning and sensor system is a change to the mobile machine that requires testing.

Therefore, after assembly, the system must be inspected by a **"person qualified to inspect"**. According to TRBS 1201 "Tests and inspections of work equipment ...", a so-called "order test" and a "technical test" must be performed as part of the test by the qualified person:

The **order test** determines, for example, whether
- the required documents are available and conclusive,
- the technical documents are consistent with the design, and
- the required test parameters have been defined (scope of testing, test intervals).

As part of the **technical inspection**, the safety-relevant features of the system are checked for condition, presence and, if necessary, function using suitable procedures. This includes, for example
- the external or internal visual inspection and
- the functional and effectiveness test.

Visual and functional check by the operator/driver

Before starting work and before each work shift, the operator/driver checks
- the function and effectiveness of the operating and safety devices,
- mirrors, CMS, warning and sensor systems for completeness, function, correct setting and cleanliness.

During operation, the mobile machine must be
- observed by the operator/driver for safe operating condition and obvious defects.
- Defects found must be reported immediately to the supervisor - and also to the relieving employee if there is a change of operator/driver.
- For reasons of safety, document any defects!

- **In the event of defects** in the CMS, warning or sensor systems that endanger operational safety, the operation of the machine must be stopped until the defects have been rectified.

Instruction

Instruction must be based on the different operating conditions and the systems used. The scope of application and the limits of the systems must also be explained and their handling must be specified!

- When using technical aids, drivers/operators must be instructed on the intended use and the necessary measures for setting, checking the functionality and maintenance.

- In the case of TAG based systems, also observe the following:

Establish rules of conduct for drivers/operators and all persons on site*, monitor compliance and enforce.

*locked and with access control - see page 24/25

Task of the employer

The employer shall ensure that work equipment (including mobile machinery and vehicles) is inspected. The purpose of the inspection is to convince himself of the correctness of a proper assembly and safe functioning of the work equipment. The inspection may only be carried out ,by persons qualified to do so.

Recurring inspections of the mobile machine:

- **Within the scope of the periodic inspections, the view must also be taken into account by the person qualified for the inspection!**

Always take into account occupational safety principles, e.g.:

- **establish organisation and delimitation of responsibility in a binding manner (who is specifically responsible for which tasks;**
- see German § 13 ArbSchG)
- **monitor compliance,**
- **carry out instructions in the appropriate languages in a way that is comprehensible to users and document them in a traceable manner;** see § 12 ArbSchG, § 81 Works Constitution Act, § 4 DGUV Regulation 1,
- **always ensure that no one is endangered; if necessary, use guides!**

7 Regulations and standards

Concerning employer

- **ArbSchG –** Occup. Safety & Health Act
- **BetrSichV –** Industrial Safety Regulation
- **TRBS 1111 –** Risk assessment
- **TRBS 1112 –** Maintenance
- **TRBS 1116 –** Qualification, instruction and assignment of employees for the safe use of work equipment
- **TRBS 1151 –** Hazards at the human-work equipment interface – Ergonomic and human factors, work system
- **TRBS 1201 –** Testing and inspections of work equipment and systems requiring monitoring
- **TRBS 1203 –** Persons qualified to carry out tests
- **TRBS 2111 Part 1 –** Mechanical hazards – Measures for protection against hazards when using mobile work equipment
- **EmpfBS 1113 –** Procurement of work equipment
- **EmpfBS 1114 –** Adaptation to the state of the art in the use of work equipment
- **EmpfBS 1201 –** Guidelines for the implementation of test requirements under various legal provisions
- **DGUV Regulation 38 –** UVV Construction work
- **DGUV Rule 101-038 –** Construction work
- **DGUV Rule 100-500 –** Operation of work equipment, Chapter 2.12 Earth-moving machinery
- **DGUV Rule 101-604 –** Civil engineering sector
- **DGUV Rule 109-009 –** Vehicle maintenance
- **DGUV Principle 301-005 –** Training and assignment of drivers of hydraulic excavators and wheel loaders
- **DGUV Testing Principle 314-003 –** Testing of vehicles for operational safety
- **StVO –** Road Traffic Regulations

- **BetrSichV Appendix 1** Exzerpt: "1.5 Before mobile self-propelled work equipment is used for the first time, the employer shall take measures to ensure that it...
e) is equipped with suitable auxiliary devices, such as camera monitor systems, to ensure that the route can be monitored if the driver's direct view is not sufficient to ensure the safety of other employees..."

- **TRBS 2111 Part 1** Excerpt: "3.2.1 (3) The employer shall take technical measures to prevent or, if that is not possible, to reduce the risk to employees from being struck, run over or crushed by mobile work equipment due to inadequate visibility (...), especially when reversing. (4) Such measures may include, for example:
  – Use of camera-monitor systems, 360-degree camera systems, additional mirrors, ...
  – Warning of mobile work equipment operators by means of systems for detecting persons or obstacles, e.g. radio-based applications, transponder and RFID detection systems."

- **StVO § 9 Paragraph. 5** excerpt: "When turning into a property, turning around or reversing, anyone driving a vehicle must also behave in such a way that other road users are not endangered; if necessary, they must ask for directions".

Recommendations for improving visibility – As an operator/employer, keep up to date with the latest technology.

- Direct vision must always have priority.
- Do not use mirror-to-mirror systems.
- Attach vision aids in the forward direction.
- Vision aids must be visible in the driver's forward 180° field of vision.
- Vision aids must not be obstructed by moving parts or by conversions or add-ons.

Checklists, e.g.

- Simplified inspection of the field of vision, DGUV expert committee on civil engineering
- View of earth-moving machines, VBG guide
- Wheel loader with light material bucket, DGUV "Fachbereich AKTUELL", FBHM-109

Concerning manufacturers:

- **MRL** – EU Machinery Directive 2006/42/EC (see note on the far right)
- **ProdSG –** Product Safety Act
- **9th ProdSV –** 9th Ordinance to the ProdSG (“Machinery Ordinance”)
- **DIN EN 474 –** Earth-moving machinery – Safety (see note on the far right)
- **ISO 5006 –** Earth-moving machinery – Field of view – Test procedure and performance requirements
- **ISO 13766 –** Earth-moving machinery – Electromagnetic compatibility of machines with internal electrical power supply
- **ISO 14401 –** Earth-moving machinery – Monitoring field of view and rear-view mirrors
- **ISO 15008 –** Requirements for display systems in vehicles
- **ISO 16001 –** Earth-moving machinery – Object-detection systems and viewing aids – Performance requirements and test procedures
- **ISO 21815 –** Earth-moving machinery – Collision warning and avoidance systems – Part 3: Danger zone and risk level – Forward/reverse movement
- **EN 300 328 –** “Radio Equipment Directive” – Wideband transmission systems
- **UNECE R46 –** Devices for indirect vision and their attachment
- **UNECE R125 –** Front field of vision
- **DGUV Test Principle GS-BAU-70 –** Principles for the testing and certification of safety-related assistance systems on machines and commercial vehicles
- **DGUV Test Principle GS-BAU-71** – Principles for the testing of personnel detection systems for earth-moving machines
- **DGUV Test Information 05: –** General principles for the safety assessment of artificial intelligence (AI)

Functional safety requirements, e.g.

- **EN ISO 12100** – Safety of machinery – General principles for design – Risk assessment and risk reduction
- **EN ISO 13849** – Safety of machinery – Safety-related parts of control systems
- **ISO 19014-2** – Earth-moving machinery – Functional safety (supersedes ISO 15998)
- **EN ISO 20607** (draft) – Safety of machinery – Instructions – General principles for design

Additional information

MRL (2006/42/EC):
The EU Machinery Directive (MRL) is replaced by the new EU Machinery Regulation. This new regulation (EU) 2023/1230 is mandatory for placing machines on the market from January 20, 2027.

DIN EN 474 and ISO 5006:
With the 2023 edition of DIN EN 474, the presumption of conformity applies again to the field of vision requirements

EN ISO 20607 (draft):
supplements the requirements of EN ISO 12100 with regard to user information and operating instructions

Concerning operators/workers:

Please note:

Even when using assistance systems, the responsibility always lies with the operator/driver. In case of doubt or having problems, inform your superior.

Always wear personal protective equipment (PPE) for your own safety and to protect your colleagues!

▶ ArbSchG (Arbeitsschutzgesetz)

§ Section 15, Paragraph 1, Sentence 1
Employees are obliged to ensure their safety and health at work to the best of their ability and in accordance with the employer's instructions and directives.

§ Section 15, Paragraph 1, Sentence 2
Employees are obligated to ensure the safety and health of persons affected by their actions or omissions at work to the best of their ability and in accordance with the employer's instructions.

§ Section 16 (1)
Employees shall immediately report any immediate significant risk to safety and health they identify to the employer.

▶ Report of overload/overload notification

A report of overload is open to any employee who is who is overburdened in any respect or feels overburdened. feels overburdened. For basic principles, see e.g. § 618 BGB, general civil law § 241 Paragraph 2 BGB, occupational health and safety law § 15 and § 16 Paragraph 1 ArbSchG. If the employee can therefore see that he is no longer able to perform his work under his own steam in such a way that damage or legal infringements can be ruled out, he must report this to his employer without delay. The employer is then in turn obliged to take remedial action. However, the employee is not released from his responsibility by such an overload notification! He must do everything within the bounds of what is possible and reasonable for him to prevent damage.

▶ Duty to support:

Employees, together with the company physician and the occupational safety specialist, must support the employer in ensuring the safety and health protection of employees at work and in fulfilling his duties in accordance with the official requirements – see § 16 Para. 2 ArbSchG.

▶ Right (and duty) to report:

If, on the basis of concrete indications, employees are of the opinion that the measures taken and resources provided by the employer are not sufficient to ensure safety and health protection at work, and if the employer does not remedy complaints from employees directed to this end, they may turn to the competent authority – see Section 17 (2) ArbSchG.

If work is to be carried out where persons are in the danger zone, the employer must implement appropriate protective measures!

Duties of the employee (driver)

- Only authorized employees may use the mobile machine.
- Observe the manufacturer's operating manual and operating instructions.
- Check the mobile machine for visible defects daily before starting operation.
- Mobile machines with defects that impair safety must not be started up or continued to operate.
- Defects in the machine must be reported immediately to the employer or supervisor.
- Use existing restraint systems.
- No persons may be transported with the working equipment of earth-moving machines.
- Only operate the mobile machine from the driver´s seat.
- Employees and other third parties must not be endangered by the mobile machine.

- **The machine operator may only carry out work with the mobile machine if there are no persons in danger zones.**

- **The following applies to colleagues: Do not stay in the danger zone of the machine!**

8 Glossary, abbreviations

Explanation of terms (in alphabetic order)

A, B, C, D

- **AI** – Artificial Intelligence
- **ArbSchG** – German Occupational Safety Act
- **BetrSichV** – German Ordinance on Industrial S & H
- **BIM** – Building Information Modeling
- **Birdview** – Bird´s eye view
- **BMAS** – German Federal Ministry of Labour and Social Affairs
- **CAN bus** – Interface for serial data exchange between control units (Controller Area Network)
- **Cyber Security** – Procedures and guidelines for defending against cyber attacks and their effects
- **CV** – Commercial Vehicles
- **DGUV** – German Social Accident Insurance

E, F, G, H

- **ECU** – Electronic Control Unit
- **EmpfBS** – Recommendation for operational safety
- **Functional Safety** – Safety on electronic control systems
- **HD** – High Definition

I, J, K, L

- **IP67** – Dust and water resistance of electronics; not robust against high-pressure cleaning
- **IP69K** – Dust and water resistance of electronics; robust against high-pressure cleaning
- **ISO** – International Organization for Standardization
- **KI** – Artificial Intelligence (Künstliche Intelligenz)
- **KMS/CMS**– Camera-monitor-mystem
- **Lidar** – Light/Laser Detection and Ranging
- **LoF** – Agriculture or forestry
- **LPS** – Local Positioning System

M, N, O

- **MLOps** – "Machine Learning Operations" optimize the transition of machine learning models into production
- **NRMM** – Non Road Mobile Machinery, e.g. construction machinery, agricultural or forestry machinery

P, Q, R

- **PPE** – Personal protective equipment
- **Radar** – Radio Detection and Ranging
- **RFID** – Radio Frequency Identification

S, T, U, V

- **SiBe/SiB** – Safety officer
- **SiFA** – Ocupational safety specialist
- **SiGeKo** – Safety and health protection coordinator
- **SKW** – Heavy-duty trucks, e.g. dumper
- **Splitscreen** Split screen view for simultaneous display of multiple camera images
- **StVO** – German Road Traffic Regulations (Straßenverkehrs-Ordnung)
- **StVZO** – German Road Traffic Licensing Regulations (Straßenverkehrs-Zulassungs-Ordnung)
- **ToF** – Time of Flight
- **TOP principle** Priority of technical measures over organizational and personal measures (see risk assessment; BetrSichV)
- **TRBS** – German Technical rules for operational safety (Technische Regeln zur Betriebssicherheit)
- **UNECE** – United Nations Economic Commission for Europe
- **UVV** – German Accident prevention regulation (Unfallverhütungsvorschrift)
- **UWB** – Ultra Wideband

W-Z,1,2,3...

- **WiFi** Wireless data transmission by radio (Wireless Fidelity)
- **3DTM** – 3D-Terrain-Mapping

Acknowledgements, legal Information

Picture credits, professional support

Network Construction Machinery NRMM CV

For over 15 years, the network members have consistently supported the development of state-of-the-art technology for the detection of persons and objects when using mobile machines and commercial vehicles: for almost all areas of application, from construction sites to the raw materials industry, agriculture/forestry, in-house transport/intra-logistics and road traffic.

The network is active wherever collisions and accidents between people, machines and materials need to be detected and avoided.
In addition to manufacturers and suppliers, experts from science and research, occupational safety and market surveillance authorities, as well as professional associations, accident insurance funds and trade unions are involved.

Further information and guidelines of the network are available on the homepage:

www.netzwerk-baumaschinen.de

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The manufacturers/developers of camera, sensor, assistance and AI systems represented in the network can be found at

https://www.netzwerk-baumaschinen.de/Hersteller.html

Specialist network for construction machinery – New Quality of Work Initiative (INQA)

In cooperation with:

BG BAU –	Employer's Liability Insurance Association Construction Industry
BGHM –	Employer's Liability Insurance Association Wood and Metal
BGHW –	Employer's Liability Insurance Association Trade and Merchandise Logistics
BG RCI –	Employer's Liability Insurance Association Raw Materials and Chemical Industry
BG Verkehr –	Employer's Liability Insurance Association Transport, Post-Logistics and Telecommunications
BMAS –	Federal Ministry of Labour and Social Affairs
BV MIRO –	Federal Association Mineral Raw Materials
IG BAU –	Industrial Union Construction, Agriculture and the Environment
KAN –	Commission for Occupational Health and Safety and Standardization
UK NRW –	Accident Insurance Fund of North Rhine-Westphalia
VBG –	German Employers' Liability Insurance Association
VDGAB –	German Association of Trade Inspectors

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