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# SMART HELMET – EVOLUTION OF PERSONAL PROTECTIVE EQUIPMENT

**Abstract:** *Safe and healthy work is a crucial prerequisite for good productivity and the success of companies. In addition to ongoing employee education, it is necessary to implement all measures to minimize risk to employees or reduce it to a statistical error. One such measure is the use of personal protective equipment. Injuries to employees' heads account for a significant percentage of accidents caused by mechanical factors or the effects of electricity. The primary step in preventing such accidents, when it comes to personal protective equipment, is to wear an appropriate protective helmet. Continuous technological improvement has been applied across various production processes and has also improved occupational safety. An example of this is a smart protective helmet, which maintains all the safety features of a traditional helmet while elevating the work process. Besides facilitating employees' daily tasks, it also contributes to enhancing their safety by monitoring vital parameters and potential dangers they might encounter.*

**Keywords:** personal protective equipment, smart protective helmet, mobile networks, high-resolution camera, sensors

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## INTRODUCTION

In an industrial environment, worker safety has become a top priority. Many employees are not sufficiently aware of occupational safety and the possible dangers they may encounter. One of the frequent injuries that occurs during work and manipulations during various production processes is a head injury.

Numerous data on occupational accidents show that the most common causes of head injuries are blows from falling objects and blows against sharp and hard objects. Head injuries caused by mechanical factors can affect the skin, skull, brain, and neck of the employee. In extreme cases, these injuries can lead to permanent disability or even death. It is not always possible to eliminate such risks only with appropriate organizational solutions or collective protective equipment.

In power plants, in addition to head injuries caused by mechanical action, injuries can also occur as a consequence of the harmful effects of electricity.

The safe and stable operation of power plants is directly related to the safety of their employees. Work on fixing plant and equipment malfunctions always represents a safety risk for all employees. Employees in other industrial branches, such as construction, railways, mechanical engineering, etc. are also exposed to the potential dangers of electricity.

In addition to the safety rules that must be followed by all employees in the workplace, wearing personal protective equipment (PPE) is of essential importance for the safe and healthy work of all employees. Personal protective equipment refers to any equipment intended to be worn or held by people at work that protects them from one or more risks to their health and safety, as well as any accessory designed to meet this objective (Ministry of Economy of the Republic of Serbia, 2020). All PPE should be used as a last resort to reduce risk, considering that the risk cannot be eliminated.

Protective helmets are one of the most commonly used pieces of PPE (Oshwiki, 2025). They are worn to protect the head from:

- impact from objects falling from above, by resisting and deflecting blows to the head;
- hitting fixed dangerous objects at the workplace;
- lateral forces – depending on the type of helmet chosen;
- open flames, splashes of molten metal, electric shock, and high temperatures.

In general, hard hats or helmets should:

- resist the penetration of objects;
- absorb shocks;
- be waterproof and slow burning; and

- contain instructions that explain the proper adjustment and replacement of the suspension and headband.

PPE designed to protect the whole body or part of it from the effects of electric current must provide sufficient isolation from the voltage to which the user may be exposed under the most unfavourable conditions.

To achieve adequate protection, the materials from which the PPE is made must be selected, designed, and installed in such a way as to ensure that the electric current that penetrates through the protective sheath is reduced and always below the maximum allowed value (Ministry of Economy of the Republic of Serbia, 2020).

Several factors must be considered when designing PPE:

- the risk of direct contact with a live conductor;
- possible harmful electrical parameters and limit values;
- skin moisture;
- the effect of contact with used chemicals such as solvents, the effect of mechanical degradation/aging, and climatic environmental factors during the normal use of PPE.

The marking of the protection class on PPE for professional use, intended for protection against electric shock, is necessary to ensure traceability and information about the scope of use and the required periodic checks.

In addition to electric shock, other risks associated with short-circuiting should be considered, such as thermal and mechanical risks.

Depending on the risk, PPE is classified into three categories (Official Gazette, 2025).

Category I includes the following minimal risks:

1) surface mechanical action;
2) contact with milder cleaning agents or prolonged contact with water;
3) contact with hot surfaces whose temperature does not exceed 50°C;
4) eye damage due to exposure to sunlight;
5) atmospheric influences that are not extreme.

Category II includes risks that are not listed in categories I and III.

Category III includes risks that can cause death or serious and permanent damage to health from:

1) substances and mixtures that are dangerous to health;
2) an atmosphere with a lack of oxygen;
3) harmful biological agents;
4) ionizing radiation;
5) environments with high temperature, the effect of which can be compared to that of air temperature of +100°C or higher;
6) environments with a low temperature, the effects of which can be compared to those of air temperature of -50°C or lower;
7) falls from a height;
8) electric shock and working under voltage;
9) drowning;
10) cuts when working with a manual chainsaw;
11) high-pressure jets;
12) gunshot wounds or stab wounds;
13) harmful noises.

According to the previous classification, PPE intended for areas where there is a potential danger of electric shock and working under voltage must meet all the conditions prescribed for category III.

## TYPES OF SAFETY HELMETS

The most common and basic form of PPE that aims to protect the employee's head is the industrial safety helmet (ISS, 2025a). These types of helmets consist of a shell, a belt, and a headband.

The helmet shell is the hard outer part of the helmet and is usually made of polyethylene, ABS (acrylonitrile butadiene styrene - thermoplastic), or fiberglass reinforced with polyester resins. The main function of the shell is to protect against a falling object or striking the user's head.

The harness is the inner part of the helmet, consisting of a system of straps made of woven straps or polyethylene. The main purpose of the harness is to absorb the energy from impact with the shell and to distribute the force evenly across the wearer's head, minimizing the risk of injury to the wearer (Oshwiki, 2025).

There are industrial workplaces where the risk of head injuries is so high that industrial safety helmets compliant with SRPS EN 397 (ISS, 2025a) are insufficient to provide an adequate level of protection. Examples of industrial sectors where such jobs exist include mining and construction. In such cases, the conducted risk assessment would identify that employees must be equipped with high-performance industrial protective helmets, i.e. helmets that comply with SRPS EN 14052 [SRPS EN 14052:2013 – High performance industrial helmets].

These helmets have the following features (Oshwiki, 2025):

- They provide the same level of shock absorption as industrial helmets, even though they are exposed to an impact with twice the energy compared to them;
- They protect the head from vertical and lateral impacts (industrial helmets do not have lateral support);
- They provide an increased level of protection against the impact of sharp objects.

### Electrically insulating helmets

If the helmet is designed to offer electrical insulation protection, it must meet the requirements of SRPS 50365 (ISS, 2025b; ISS, 2025c).

To mitigate the risk of hazardous electrostatic charge accumulation, helmets shall incorporate one of the following protective measures (SIST, 2025):

- Use of Dissipative Materials: Employ materials with dissipative properties that can be reliably earthed, typically via contact with the wearer, ensuring effective discharge of electrostatic charges;
- Use of Insulating Materials with Low Chargeability: Utilize insulating materials that exhibit minimal tendency to accumulate static charge through triboelectric interactions with clothing under normal operating conditions. If insulating materials are present, electrostatic charging tests shall be performed using fabrics from both ends of the triboelectric series. In cases where corona discharge and leather glove whipping tests are omitted, it must be explicitly stated in the user documentation that the helmet is not suitable for environments where electrostatic charging exceeds levels typical of manual rubbing;
- Non-Accessible Insulating Components: Insulating materials located in areas of the helmet that are not accessible during operation are exempt from triboelectric charging tests, as they are not subject to mechanical interaction or friction.

In addition, any accessible isolated conductive components within the helmet are considered isolated capacitances and must comply with the requirements specified in IEC TS 60079-32-1 (ISS, 2025d).

## FROM PASSIVE GEAR TO ACTIVE SAFETY SYSTEMS

The rapid development of science and technology has enabled the application of adequate technological solutions to improve occupational safety and protection in the form of modernized PPE. The three main requirements when designing intelligent protection are personnel safety, equipment safety, and environmental safety. The combination of video intelligence and wireless communication was aimed at active warning, intelligent decision-making, and automatic inspection, improving the ability of people to detect faults, the ability to control operations and maintenance, possibilities of emergency warning and response, remote control, and the like.

One of the representatives of intelligent protection is a smart helmet (Figure 1).

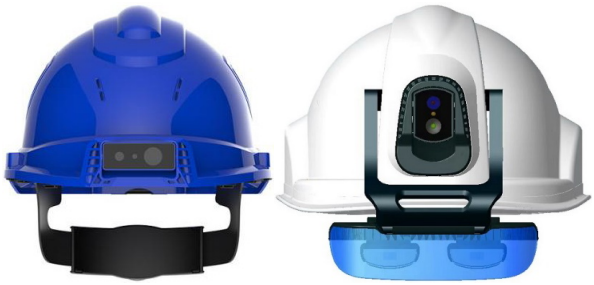

**Figure 1.** *Smart helmet (Ouxiang International Limited, 2025; Jepower, 2025)*

Smart helmets have been widely applied in the power industry (Figure 2), railways (Figure 3), construction (Figure 4), steel industry, docks, etc. In some industries, such as aerospace and energy, workers or managers using smart helmets can command and solve problems in real time. Smart safety helmets provide a high level of protection, preventing workers from head impacts, stab wounds, and other injuries (Ouxiang International Limited, 2025; Jepower, 2025; Elefine, 2025).

**Figure 2.** *Smart helmet in the power industry (Ouxiang International Limited, 2025; Elefine, 2025)*

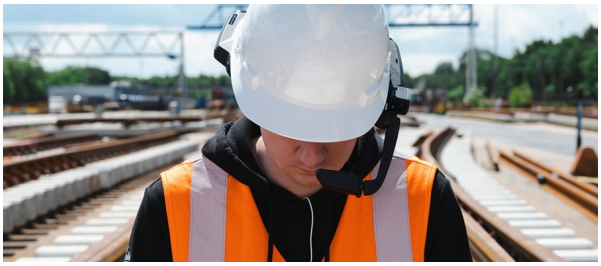

**Figure 3.** *Smart helmet in railways (Railpro, n.d.)*

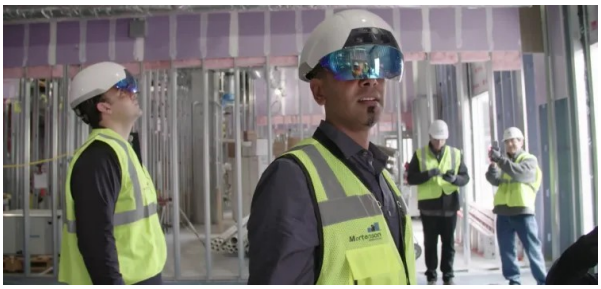

**Figure 4.** *Smart helmet in construction (Palladino, 2017)*

The smart helmet is an intelligent mobile operating terminal that supports secure communication via mobile and Wi-Fi networks. It has integrated high-speed processors, a high-resolution camera, a wireless communication module, various sensors, and the like (Figure 5).

The high-resolution camera has video recording, picture taking, storage, and night light functions. Recording can be used for evidence gathering, remote guidance during maintenance, security monitoring, intelligent early warning, etc. (Ouxiang International Limited, 2025).

The smart helmet can make real-time audio and video calls and real-time video surveillance. Communication with other devices, such as smartphones or computers, via mobile network, Wi-Fi, or Bluetooth is enabled (Jepower, 2025). A smart helmet can transmit audio and video material to the dispatch centre in real time. A person wearing a smart helmet can initiate an audio or video call with the centre with the push of a button. The

communication is two-way, so the dispatcher can initiate a call from a remote location at any time and simultaneously record images displayed by multiple smart helmets. Two-way communication is not limited to a small area, which significantly facilitates work in remote and less accessible areas (Elefine, 2025).

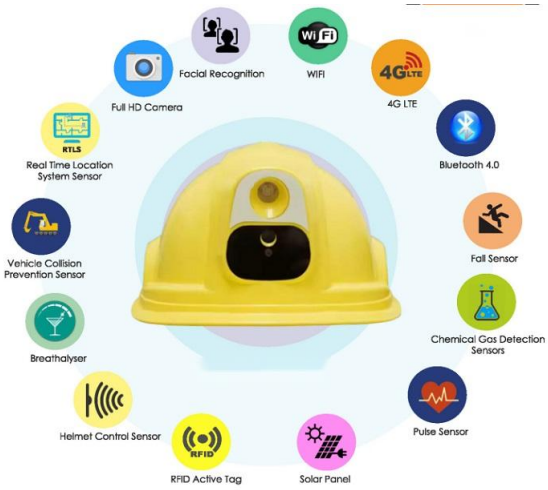


**Figure 5.** *Smart helmet functions (Ouxiang International Limited, 2025)*

They usually contain multiple sensors, such as accelerometers, gyroscopes, temperature sensors, and perception sensors. These sensors are used to detect environmental parameters, such as temperature, humidity, and light.

They can record various parameters, e.g. workers' working hours, location, task performance, and other data, and transmit this information to the centre for analysis (Jepower, 2025; Elefine, 2025).

They have the option of GPS positioning and the option of multiple alarms, such as a safety alarm, a fall alarm, a crash alarm, a helmet removal alarm, a silent alarm, and other functions.

The automatic alarm function is essential, as it enables immediate recognition of dangerous and unwanted situations, and timely action and assistance on the spot (Elefine, 2025).

Some smart helmets can be equipped with Augmented Reality (AR) or Virtual Reality (VR) functions, providing workers with more intuitive job guidance and better training (Jepower, 2025).

The smart AR helmet may have a brainwave interface, heart rate monitoring, and other functions. The brainwave collection function can monitor the worker's physical fitness and emotions in real-time, and judge and give an early warning for further fitness for work. Safety accidents often occur when personnel work in harsh environments (Ouxiang International Limited, 2025).

Smart safety helmets usually have built-in batteries and charge management systems. In this way, full mobility and long-term use were achieved. The design is adapted to the comfort of workers when wearing it. They are made of light and breathable materials to increase comfort during long hours of wear (Jepower, 2025).

## CONCLUSION

All employees working in areas where there is a possible risk of head injury from impact, falling or flying objects, or electric shock and burns, must be protected by protective helmets. Protective helmets must be worn when performing most construction work, work near lifting equipment (cranes, etc.) and suspended loads, and work in forestry, tanks, wells, shafts, tunnels, etc.

In some situations, protective helmets serve as the basis for other types of PPE, i.e. are used together with other PPE, e.g. hearing protection, face shields, or respiratory protection equipment.

All work related to the selection, maintenance, training for safe use, inspections, and maintenance of the register of protective helmets is the responsibility of the employer. A risk assessment may stipulate that the user must wear a protective helmet during the entire shift. Also, the employee is responsible for using protective equipment for its intended purpose. He will also be obliged to inform the employer or the appropriate occupational health and safety representative of any defects in this equipment. However, it should be remembered that the use of helmets does not eliminate dangerous factors, but only reduces the severity of their consequences.

Thanks to their technology, smart helmets have become an excellent tool for performing essential and everyday tasks, without diminishing the safety role they play as a representative of PPE. With their capabilities, they raised occupational safety and health to a higher level.

They can be used in power inspections, site inspections, remote operations, explosion monitoring, rescue and disaster relief, remote guidance for maintenance, police forces (interventions, traffic, patrols), coast guard forces, fire control, emergencies, etc.

They are equally useful both for real-time communication and for archiving data collected from the field, as well as for the safety of the employees themselves. They are particularly suitable for evidence gathering, remote guidance during maintenance, security surveillance, early warning, real-time communication, and real-time video surveillance. They raise the safety of employees to a higher level by determining the location of employees in real time and by alarming both employees and the control centre, which contributes to timely action and on-site assistance. Some smart helmets monitor the wearer's vital functions and assess the mental and physical state of employees at a given moment.

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