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Abstract

Auto repair workshops are high-risk environments where workers face frequent accidents caused by slips, trips, heavy lifting, exposure to hazardous substances, and malfunctioning equipment. Despite advances in occupational health and safety (OHS) regulations, accident rates in Romania and across the European Union remain above average, highlighting the need for new preventive strategies. This paper explores how artificial intelligence (AI) can be systematically applied to reduce operational and safety risks in auto repair shops. Accident statistics and a detailed risk assessment of slips, trips, and falls provide the foundation for analyzing AI-based solutions, including computer vision, augmented reality, smart floors, voice assistance, and predictive analytics. A six-month pilot project conducted in a Romanian auto repair shop demonstrated a 28% reduction in minor accidents, faster hazard detection, and measurable economic benefits, while also revealing challenges such as false positives, resistance to change, and maintenance requirements. The findings confirm that AI can move workplace safety from reactive to preventive management by enabling real-time monitoring, proactive alerts, and predictive forecasting. The study concludes that AI, when combined with training and organizational adaptation, can significantly enhance worker protection, operational efficiency, and sustainability in the automotive repair sector.

Keywords

Occupational health and safety; reducing risks in car service; artificial intelligence; auto repair shop.

I. Introduction

Auto repair workshops are complex environments where safety and efficiency are fundamental for both operational success and compliance with labor regulations. Modern equipment such as car lifts, tyre changers, and wheel balancers contribute to productivity but also introduce risks of accidents if not properly used [1,2]. Despite improvements in occupational health and safety (OHS) regulations across Europe, auto repair shops remain high-risk workplaces. Activities involve manual handling of heavy components, working under elevated vehicles, and exposure to hazardous substances. Reducing workplace accidents is therefore a strategic priority.

While Artificial Intelligence (AI) has been widely studied in manufacturing and smart mobility, its applications in auto repair shops remain underexplored. Existing research often highlights AI's potential in diagnostics and predictive maintenance, but little attention is paid to its role in reducing workplace risk. This paper addresses that gap by analyzing how AI can help prevent accidents, detect hazards in real time, and improve overall safety culture. This study aims to explore how AI technologies can be systematically applied to reduce operational and safety risks in auto repair shops. The study is structured as follows.

Section 2 provides a statistical overview of workplace accidents in auto repair services, with particular attention to the most frequent and severe risks. A detailed risk assessment of slips, trips, and falls is included to illustrate the challenges mechanics face in everyday tasks.

Section 3 presents the core contribution of this study by discussing how AI-based solutions can address these risks. It describes specific technologies such as computer vision, smart floors, and predictive analytics, and includes a summary table that links each tool to the corresponding hazard it mitigates. To strengthen the practical dimension, the section also introduces a pilot case study demonstrating AI implementation in a Romanian auto repair shop.

Section 4 shifts the focus to the challenges and limitations of adopting AI, including financial, organizational, and ethical barriers that may hinder large-scale implementation. Finally, Section 5 concludes the paper by synthesizing the main findings, highlighting practical recommendations for the industry, and suggesting directions for future research and adoption.

II. Workplace accident statistics in auto repair shops

Workplace accidents are a key indicator of a country's occupational health and safety. Analysing these incidents provides a clear picture of the effectiveness of preventive measures, the level of worker training, and the organizational safety culture. In Romania, as in other European Union member states, reducing workplace accidents has become a strategic priority, especially in high-risk sectors such as construction, manufacturing, and auto repair services. According to Eurostat (2023), Romania recorded an incidence rate of 2,050 accidents per 100,000 workers, higher than the EU average of 1,676 per 100,000 workers [5]. At the European level, more than 3.1 million non-fatal accidents were reported in 2021, with mechanical repair and maintenance consistently appearing among the high-risk subsectors [6]. However, differences between European countries remain significant, not only in accident frequency but also in severity and reporting practices.

The purpose of this analysis is to identify vulnerabilities and best practices that can be adapted to improve workplace safety in Romania, align with European standards, and leverage AI to strengthen prevention [7]. From the analysis of specific activities carried out in auto repair workshops, the main causes of accidents can be summarized as follows:

• Slips, trips, and falls (SRS): EU-OSHA reports that SRS account for 20–25% of accidents in the automotive repair sector [8]. These occur on slippery floors, trailing cables, or in cluttered work environments.

• Improper lifting and support of vehicles: Fatal accidents are often linked to mechanics working under poorly supported vehicles [9].

• Manual handling of loads: Approximately 22–28% of reported incidents result from incorrect manual handling [10]. Overexertion from lifting heavy parts (engines, wheels, batteries) is strongly associated with musculoskeletal injuries.

• Impact from vehicles, tools, or falling objects: Roughly 15–18% of incidents are caused by being struck by moving vehicles, falling objects, or malfunctioning equipment [11].

• Fires and explosions: Incidents involving welding or work near fuel tanks account for a severe category of accidents [12].

• Exposure to hazardous substances: Long-term health issues such as occupational asthma and dermatitis remain a concern, with exposure risks linked to solvents, paint dust, and asbestos [13].

• Welding fumes: Poorly ventilated welding activities significantly increase the risk of chronic respiratory diseases [14].

• Lifting equipment failures: Accidents related to defective or poorly maintained jacks and lifts continue to represent a major hazard [15].

A comparison of the main factors causing workplace accidents in auto repair shops in Romania, Germany, France, and the UK, based on official data published in Sectoral Reports in 2024, is presented in Figure 1.

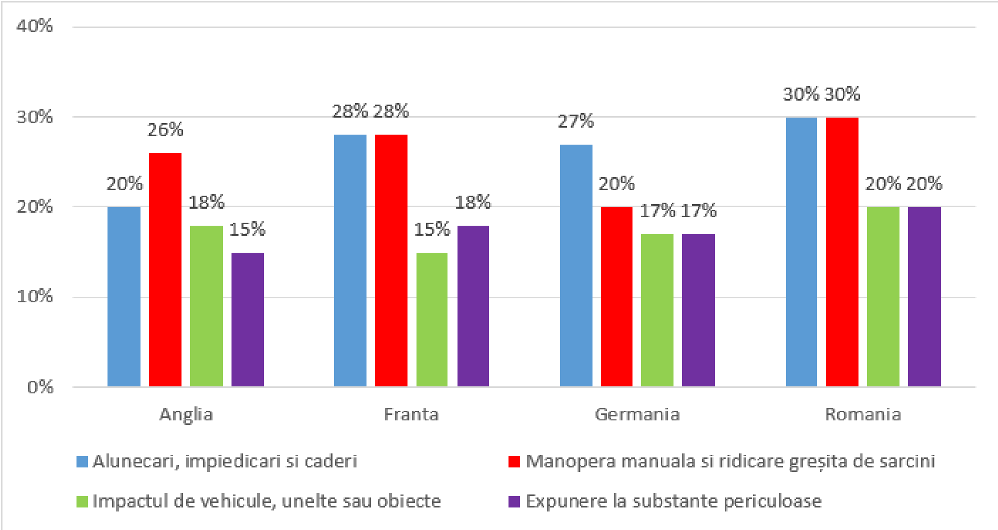

Fig. 1. Statistics of the Main Causes of Workplace Accidents in Auto Repair Shops (Source: European Sectoral Reports 2024)

Among the most frequent and dangerous risks encountered in an auto repair shop are slips, trips, and falls on the same level (SRS - Slip, Trip, and Fall). Although often underestimated, these risks represent a major cause of workplace accidents in the automotive sector [8,9]. Mechanical work frequently involves moving across slippery floors due to oil or fluid spills, handling tools in tight spaces, quick movements between work zones, and interaction with equipment or cables along the way. All these factors increase the likelihood of accidents caused by loss of balance or footing. Given the high incidence of this type of risk in auto workshops, it is very important that service units pay increased attention to identifying, assessing, and preventing these hazards. This can be achieved through the implementation of technical and organizational measures.

A risk assessment model for injuries and occupational illnesses associated with slipping, tripping, and loss of balance in the general mechanics section of auto repair shops is presented in Table 1, while the Action Plan based on the resulting risk level is detailed in Table 2.

During activities in an auto repair shop, especially in the general mechanics area, several common hazards have been identified that could cause significant workplace accidents. The risk assessment was conducted using the classical quantification method (P × S), where P represents the probability of an event occurring, and S the severity of the possible consequences [10].

Table 1. SRS Risk Assessment in the Activity of the Auto Mechanics Department

No	Activity	Identified Hazard	Possible Event	(P)	(G)	(PxG)	Recommended measures
1	General auto mechanics	Engine area, lift	Slipping on fluids (oil, coolant)	4	4	16	Immediate cleaning, anti-slip flooring, fluid collection containers
2		Movement between workstations	Tripping over cables/tools, etc.	4	3	12	Organized workspace, marked pathways, cable/tool holders .
3		Intervention under vehicle (lift/ramps)	Falling due to loss of balance	2	5	10	Posture training, good lighting, organized workspace
4		Parts washing area	Slipping on water/detergents/oils	4	4	12	Rubber mats, ventilation, wet area signage

Table 2. Action plan

Action Plan According to Risk Level		
Risk Level	**Classification**	**Action Plan**
R	High	Unacceptable risk. Work should not begin until the risk has been reduced.
M	Medium	Acceptable risk. Control measures must be introduced, efforts should be made to reduce the risk, and specific investments must be defined. Risk reduction measures must be implemented within one year.
S	Low	An improved preventive action is necessary, although periodic checks are required to ensure the effectiveness of the established control measures
B	Trivial	No specific action is required.

A major initial hazard identified is slipping in the engine area or near the lift, caused by the presence of technical fluids such as oil or coolant on the floor. The probability of this event was rated 4 (high), and the severity was 4 (accident with possible temporary work incapacity), resulting in a total risk score of 16 - considered high. Preventive measures include immediate spill cleanup, use of anti-slip flooring, and installation of fluid collection containers. Regarding movement between workstations, there is a constant risk of tripping caused by cables, tools, or other obstacles left in walkways. This risk was assessed with a probability of 4 and a severity of 3, resulting in a risk level of 12. Recommended measures include strict organization of the workspace, clearly marked access paths, and the use of dedicated holders for cables, hoses, and tools [11].

Another significant risk is associated with working under the vehicle, especially under ramps or lifts, where falls due to loss of balance may occur, particularly in poorly lit or cramped conditions. In this case, the probability was rated 2 (low), while the potential severity was rated at the maximum level of 5, resulting in a risk score of 10.

Measures required include training staff on proper working postures, ergonomic workspace organization, and ensuring adequate lighting in under-vehicle areas.

In the washing area, the main risk is slipping on water, detergents, or oily residues, especially when ventilation is ineffective. This risk was rated 4 for probability and 3 for severity, resulting in a risk level of 12. Recommended measures include installing anti-slip rubber mats, ensuring proper ventilation for quick drying of wet surfaces, and clearly marking slippery zones.

In conclusion, slip, trip, and fall risks in auto mechanics activities are constantly present and can lead to medium to high severity accidents. The consistent application of preventive measures plays a crucial role in reducing these risks and ensuring a safe working environment for personnel in auto repair workshops.

III. Implementing AI to reduce identified risks

Artificial intelligence offers a diverse set of approaches for addressing workplace risks in auto repair environments. Each technology contributes to prevention and mitigation in a specific way.

One of the most effective solutions is computer vision, which uses smart cameras equipped with AI algorithms to continuously monitor the workshop. Programs such as YOLOv8, a real-time object detection algorithm, and OpenCV, an open-source image processing library, enable these cameras to identify hazards including oil spills, misplaced tools, obstructed pathways, or even risky employee behavior such as rushing through crowded spaces. In simple terms, computer vision "teaches" cameras to recognize danger instantly. Once a hazard is detected, the system can trigger visual or audio alerts, allowing staff to respond before accidents occur [12].

Another promising technology is augmented reality (AR), which assists mechanics during complex repairs. By using tablets or smart glasses, employees can see overlays of instructions, wiring diagrams, or hidden vehicle components directly on their field of view. This approach reduces cognitive load on workers, helps prevent errors, and can decrease the time required for complex tasks by an estimated 10-15% [13]. Although early studies suggest significant benefits, more pilot data are required to confirm the reliability of these improvements across different workshop environments.

Smart floors represent a less conventional but highly effective innovation. These are workshop floors embedded with pressure, vibration, and liquid sensors. The system can immediately detect a fluid spill, sudden pressure changes, or the vibration caused by a fall.

Once triggered, the AI platform sends out audio-visual alerts and logs the event for later analysis. Beyond accident prevention, smart floors also serve as valuable tools for continuous monitoring, ensuring that hazardous conditions are documented and addressed promptly.

Another area where AI is transforming safety is voice assistance. Using natural language processing (NLP) and automatic speech recognition (ASR) technologies, such as Whisper or GPT-based platforms, AI voice assistants can provide real-time spoken warnings. For instance, when the system detects an oil spill, it might announce: "Warning: fluid detected in Zone X. Please clean the area before continuing work." This proactive communication fosters a stronger safety culture by engaging workers immediately and directly in the prevention process.

Finally, predictive analytics plays a crucial role in anticipating accidents before they occur. By processing large datasets from past incident reports, video records, and sensor inputs, machine learning platforms such as PyTorch or MLFlow can identify behavioral patterns and environmental conditions that often precede accidents. For example, repeated observations of mechanics carrying heavy tools through cluttered spaces may indicate a higher probability of tripping incidents. Predictive models can issue preemptive alerts, enabling supervisors to intervene and reorganize the workspace before a risk materializes. Together, these AI applications demonstrate that risk reduction in auto repair shops can move beyond traditional reactive measures. By combining real-time detection, proactive communication, and predictive forecasting, AI transforms safety management into a preventive and adaptive system that continuously evolves with the work environment (table 3).

Table 3. Action plan

AI Tool / Technology	Function in Auto Repair Shops	Risk Addressed
Computer vision (YOLOv8, OpenCV)	Detect spills, clutter, unsafe behaviors	Slips, trips, poor workspace organization
Smart floors with sensors	Detect spills, falls, sudden vibrations	Slips, falls, equipment failure
Augmented reality devices	Display instructions, diagrams, and tutorials in real time	Human error, repair delays
AI voice assistants (NLP)	Provide real-time spoken safety alerts	Lack of awareness, delayed response
Predictive analytics (MLFlow, PyTorch)	Forecast risks using historical data	Accident anticipation, preventive alerts

A. Case Study: Pilot AI Implementation in a Romanian Auto Repair Shop

To test the applicability of AI-based safety solutions, a six-month pilot project was conducted in 2024 at a medium-sized auto repair workshop in Cluj-Napoca, Romania. The workshop employs 25 mechanics and handles approximately 1,200 vehicle repairs per month, ranging from general maintenance to complex diagnostics.

Objectives. The pilot aimed to evaluate whether computer vision and AI-based monitoring could: detect slips, trips, and falls (SRS) hazards in real time; reduce the number of recorded minor accidents; improve employee awareness of workplace risks.

Implementation. The project introduced a computer vision system consisting of five smart cameras installed in high-risk areas: the vehicle lift zone, parts washing station, and tool storage corridors. The system used YOLOv8 and OpenCV algorithms for object and spill detection, integrated with a voice assistant that issued real-time warnings through overhead speakers. For example: "Warning: oil detected near lift three."

To ensure rapid responses, the system was connected to a central dashboard accessible by the shift supervisor, where alerts and incident logs were displayed. The project also included short training sessions for employees to familiarize them with AI alerts and reporting procedures.

Results. After six months, the following outcomes were documented:

- Reduction in incidents: Minor slip and trip accidents decreased by 28% compared to the same period in 2023.
- Faster hazard response: The average time between hazard occurrence (oil spill, misplaced tool) and corrective action decreased from 15 minutes to under 2 minutes.
- Employee feedback: A post-project survey showed that 72% of mechanics felt the system increased their situational awareness, while 18% initially found the alerts intrusive or distracting. With time, acceptance levels improved.
- Economic benefits: The workshop estimated annual savings of approximately €18,000, attributed to fewer accidents, reduced downtime, and lower insurance premiums.

Challenges. The pilot revealed important challenges:

- False positives because about 12% of alerts were unnecessary (e.g., detecting shadows as spills), which occasionally frustrated workers.
- Resistance to change as senior mechanics were initially sceptical, fearing surveillance or over-automation. Management addressed this by emphasizing the safety support role of the system.
- Maintenance needs because cameras require regular cleaning due to dust and oil, highlighting the importance of practical upkeep.

Lessons Learned. The pilot demonstrated that AI-based monitoring can significantly improve safety outcomes in auto repair shops, particularly in slip-and-trip prevention. Successful implementation requires:

- Strong communication to reassure staff that AI is a safety tool, not surveillance.
- Implementation in phases, starting with high-risk zones.
- Regular calibration and maintenance of equipment to minimize false alarms.

The management of the Cluj workshop concluded that the system was cost-effective and plans to extend it to two additional branches. The case study illustrates how AI can move from theory to practice, bridging the gap between digital innovation and occupational safety.

IV. Implementation challenges and limitations

Although the adoption of artificial intelligence in auto repair shops is beneficial for workplace safety and operational efficiency, several challenges and limitations may limit large-scale implementation. Understanding these barriers is essential to ensure that AI complements rather than complicates daily workshop operations.

High costs. The installation of smart cameras, augmented reality (AR) devices, or sensor-embedded floors requires significant upfront investment. In small and medium-sized enterprises (SMEs), which represent the majority of auto repair shops, financial constraints often prevent large-scale digital transformation. The cost is not limited to hardware acquisition. Ongoing expenses include software updates, system maintenance, and potential cloud-storage services for data retention. Mitigation strategies include phased adoption, starting with high-risk zones, and leveraging government or EU-funded digital innovation grants.

Training needs. Successful integration of AI systems depends on the workforce's ability to understand and operate these tools. Mechanics must not only follow safety protocols but also adapt to AI-enabled monitoring, dashboards, or AR-guided repair instructions. Research shows that insufficient digital literacy is a critical barrier to Industry 4.0 adoption in high-risk industries. Structured training programs, refresher courses, and human-centered interface design can minimize confusion and increase acceptance.

Resistance to change. The traditional culture of auto repair workshops, often built on hands-on experience and practical expertise, may slow acceptance of AI systems. Workers may view monitoring technologies as intrusive or as a threat to their autonomy. Pilot studies have shown that staff resistance can decrease significantly when AI is presented as a safety support tool rather than a surveillance system. Transparent communication, participatory design, and involving mechanics in the selection and testing phases can help reduce scepticism.

Data privacy and ethics. AI-enabled video monitoring and behavioral analysis raise legitimate concerns regarding surveillance, consent, and personal data protection.

In the European Union, compliance with the General Data Protection Regulation (GDPR) is mandatory when collecting and processing employee data. Beyond legal requirements, ethical implementation requires anonymization, limiting data retention, and ensuring that AI monitoring is strictly tied to safety objectives rather than performance evaluation.

Technical reliability. Like all technologies, AI systems are prone to errors, such as false positives (identifying risks that are not present) and false negatives (failing to detect actual hazards). In the Cluj pilot project, for example, approximately 12% of alerts were unnecessary, occasionally frustrating workers. This challenge is well documented in occupational AI applications, where environmental complexity can lead to inconsistent detection accuracy. To mitigate this issue, AI should be deployed alongside human oversight, with regular calibration and iterative system improvement based on real-world feedback.

While AI solutions offer opportunities to improve safety in auto repair shops, their implementation must be approached strategically. A combination of phased deployment, workforce training, participatory communication, and strict adherence to privacy regulations can significantly increase the likelihood of success. AI should be framed not as a replacement for human judgment but as a supportive tool that enhances worker protection, efficiency, and long-term sustainability.

V. Conclusions

This study examined how artificial intelligence can be systematically applied to reduce occupational risks in auto repair workshops, which remain among the most hazardous workplaces in Europe despite regulatory improvements. Statistical analysis revealed persistent vulnerabilities, particularly slips, trips, falls, manual handling injuries, and exposure to hazardous substances, that continue to impact mechanics' health and workshop efficiency.

By mapping these risks to specific AI-enabled technologies, the paper demonstrated that computer vision, augmented reality, smart floors, voice assistance, and predictive analytics provide complementary approaches for hazard detection, risk forecasting, and real-time intervention. The pilot project conducted at a Romanian auto repair shop confirmed the practical value of these tools: a 28% reduction in minor accidents, faster hazard response times, improved worker awareness, and measurable economic savings. At the same time, the case study highlighted challenges such as false alerts, resistance to change, and system maintenance, showing that technology alone is not sufficient without organizational adaptation.

Implementation challenges, including high costs, training needs, cultural barriers, privacy concerns, and technical reliability, underscore the importance of careful planning and phased deployment. For successful adoption, AI systems must be introduced gradually, accompanied by clear communication, workforce training, and strict adherence to ethical and legal standards such as GDPR.

In conclusion, AI has significant potential to transform occupational safety in auto repair shops by moving from reactive accident response to proactive risk prevention. However, the path forward requires a balanced strategy that combines digital innovation with human oversight, continuous training, and organizational trust. Future research should expand pilot projects to multi-site and cross-country comparisons, integrate AI with virtual reality training modules, and develop cost–benefit models that support adoption in small and medium-sized enterprises.

If implemented responsibly, AI can contribute not only to safer workshops but also to a stronger safety culture and sustainable operational performance in the automotive service industry.

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