Managing the maintenance activity of electric vehicle charging station networks to guarantee the health and safety of workers

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Abstract. The achievement of European and national targets and objectives regarding the installation of alternative fuel infrastructure to utilise zero-emission propulsion technologies in the road sector through the application of economic incentives has led to the development of electric and hybrid vehicle fleets and the establishment of electric vehicle recharging infrastructure. The paper presents the results of research studies on diagnosing technological and occupational risks generated by the maintenance activities of the electricity supply infrastructure for road transport. The validation and evaluation of the models of electric charging stations in use highlighted for maintenance personnel a series of significant electrical risks, including those generated by electrical short circuits and mechanical failures, as well as the risk of fire associated with the heating of the electric vehicle's battery during charging. In order to manage technological risks and occupational risks generated in the maintenance activity of electric vehicle charging station networks, the general decision support system (DSS) was developed so that by identifying the risks of occupational accidents and illnesses, implementing security measures, planning and organising preventive maintenance and corrective maintenance activities, the risks for workers and users are minimised.

1 Introduction

Mobility and accessibility are key prerequisites for meeting the requirements for "0%" carbon emission mobility in the polycentric European territory, including in the countries neighbouring the Union. In this regard, at the European Union (EU) level, rigorous regulations have been established, aligned with the decarbonization and energy transition objectives, which oblige EU countries to accelerate the transition to a greener and more sustainable transport system by increasing the fleet of "0%" carbon emission vehicles and facilitating the installation and development of alternative fuel infrastructure. [1-3]

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The analysis of statistics recorded at EUROSTAT, the European Alternative Fuels Observatory and the National Statistics Institute (NSI) shows, in the last five years, both at the EU and national level, an increase in both the number of road electric vehicles (EV) and plug-in hybrid road vehicles (PHEV) and the number of publicly accessible electric recharging points. Figure 1 graphically presents the evolution in Romania of the registrations of electric road vehicles (EVs) and plug-in hybrid road vehicles (PHEVs), as well as the public charging points put into operation from 2020 to 2025. As a result of the facilities provided by the Romanian state to meet the proposed targets for reducing carbon emissions, an approximately exponential increase in the EV and PHEV fleet has been observed over the last five years, as well as in the recharging infrastructure. From the analyzed statistical data, no data was identified on the number of electric vehicles and plug-in hybrid vehicles registered by May 2025.

Compared to other EU countries, Romania ranks in the middle in terms of the number of publicly accessible electric recharging points installed and in service.

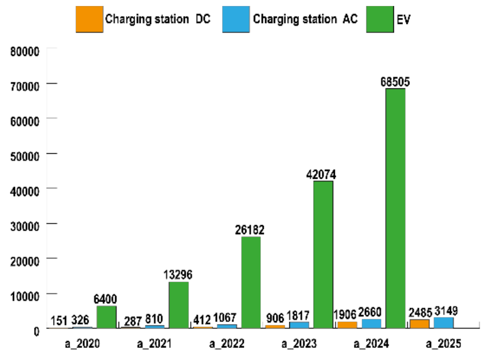

Fig. 1. Number of electric vehicles (EV) and public charging points in Romania, during 2020-2025
Source: NSI - TEMPO program 2025 and European Alternative Fuels Observatory [4, 5]

Studies conducted on the use of "0%" emission technologies in the road sector, respectively, the fleet of battery electric road vehicles and plug-in hybrid electric vehicles, have highlighted their uneven share and distribution from one country to another [1, 2].

Analysing the TENtec interactive mapTENtec (European Commission's Information System to coordinate and support the Trans-European Transport Network Policy (TEN-T)) and data from the Plugshare portal, at the level of June 2025, there is a non-uniformity of public charging locations with unrestricted access 24/7 in the European Union as a result of a different approach to the implementation of the European Directive and national policies.

In Romania, the electric vehicle fleet and recharging infrastructure have developed significantly in recent years, but there are notable differences between the capital and large cities, as well as rural areas. In large cities, the number of EVs, PHEVs and charging points is increasing; there are both public stations in shopping mall parking lots and public and private residential parking lots. EV recharging points primarily include fast (over 50 kW) or ultra-fast (over 150 kW) charging stations, which enable rapid charging of EV batteries, as well as alternative current charging stations with medium charging capacity [4-6]. Figure 2 illustrates the distribution of public charging stations in Romania as of May 2025, categorized by battery recharging power.

In many rural areas or on less travelled transit roads, the infrastructure remains insufficient, which implies for EV users, careful planning and analysis of the travel route, depending on the autonomy of the electric vehicle and the accessible charging points, respectively, the type of charging stations and the type of connectors in their component.

To implement Regulation (EU) 2023/1804, Romania must develop and install fast and high-speed charging stations with an adequate number of charging points, ensuring at least one fast-charging point every 60 km on major roads. Their adequate distribution is essential to ensure that all users have quick and easy access to charging points, regardless of their location (motorways, national roads), especially on rural roads. It is also necessary that existing stations are interoperable and accessible 24/7, including through the integration of standard payment solutions.

The Regulation (EU) 2023/1804 imposes clear deadlines for the development of alternative fuel infrastructure throughout the European Union, including in Romania. Its implementation depends on several factors, including administrative measures, financing, and coordination between public authorities and the private sector.

Romania has included the development of alternative fuel infrastructure as part of its investment and reform plan under the European-funded National Recovery and Resilience Plan and has secured funding for the installation of over 2,000 charging stations. A significant percentage of these must be fast and ultra-fast charging stations to standardise and complete the network of charging points on motorways and national roads, thereby meeting the requirements of the European regulation, which stipulates that at least one fast-charging point must be available every 60 km on European and national roads.

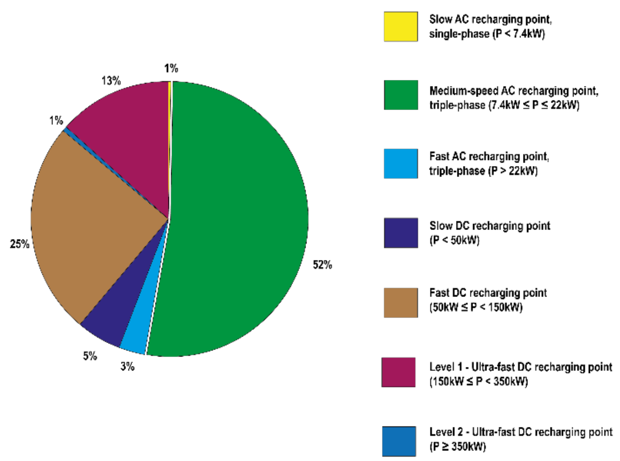

Fig. 2. Share of public charging stations in Romania, May 2025

Source: European Alternative Fuels Observatory and NSI - TEMPO program 2025 [4,5]

2 Technical and occupational health and safety requirements regarding the maintenance of EV recharging points

The maintenance of the charging infrastructure for electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs) is of particular importance in terms of ensuring the operational safety, reliability, availability, and durability of the infrastructure, as well as the safety and security of users (drivers and passengers) and maintenance operators. As electric mobility becomes an integral part of community and company infrastructure, the maintenance of these stations becomes essential [2].

The paper presents the results regarding the maintenance of the infrastructure for the supply of electric energy for road transport developed within the study "Operational study of the specific problems in the field of car power supply, identifying the main problems, identifying risks and consequences that may result from an unforeseen event that turns into an accident Risk structure - causes – consequences".

The study analyzed the electricity supply infrastructure for road transport, starting from the analysis of the applicable legislation of the European directives and subsequently of Regulation (EU) 2023/1804 of the national legislation and the applicable technical regulations in order to establish the safety and health requirements both from the design and manufacturing phase, as well as in use, starting from installation, commissioning and inspections.

The case studies focused on fixed AC and DC electric vehicle recharging stations (recessed in the floor, wall or on the pedestal), for which:

- identified, diagnosed and assessed technical non-conformities in the design, manufacture and installation of recharging stations;
- identified and analysed and assessed technological risks and risks of occupational accidents and diseases, reported work-related incidents and accidents.
- analysed the content of the technical books/instructions for use of electric vehicle recharging stations. The technical books/instructions for use must cover both normal use and any abnormal use (verifying that the EV is properly connected; verifying the continuity of the protective conductor; etc.) as well as maintenance specifications. Particular attention was paid to warning users about the use of non-compliant adapters and extension cords, respectively the warning about improvisations, warnings that reduce the risk of overheating of the electric vehicle battery, respectively the risk of fire and the risk of explosion.
- established the technical and occupational health and safety requirements regarding basic maintenance (preventive and corrective), which may differ depending on the type and characteristics of the component stations of the recharging points.
- established the recommended additional maintenance steps, optional if necessary, depending on the location, environmental conditions, the way the recharging point is supplied with electricity, the protection systems adopted against electrical risks, the complexity of the IT systems for monitoring and remote control (error reports, call logs, etc.), etc.

The analysis, diagnosis, and evaluation of technical non-conformities, as well as technological risks and risks of occupational accidents and illnesses, and the causes that generated work accidents or events, were the preliminary stages in establishing and developing the risk-causes-consequences-prevention measures structure [2, 3].

The activity of EV charging station maintenance operators is carried out mainly in the areas where they are located, so in addition to the technological risks of accidents generated by EV charging stations and the work equipment used in the activity, special emphasis was placed on the external risks generated by the location (residential area/market/road, underground/aboveground parking), by the neighbourhoods including the neighbourhood with electric vehicles being charged.

The electric vehicle (EV) recharging process is a process that, due to technical and/or human errors, can generate technological risks and risks of occupational accidents and illnesses, including electrical risks, thermal/fire risks, and explosion risks. These risks have been integrated into the risk-causes-consequences-prevention measures structure. It was taken into account that both maintenance operators, users, and people in the area are exposed to these risks, and the material costs are significant [3].

Statistically, it has been found that the risks in the electric vehicle recharging process are most often caused by electric battery failures, primarily due to overcharging. These causes are studied, and various evaluation and monitoring methods have been developed, starting from the battery manufacturing process, where the manufacturing flow and especially the quality of the materials used are evaluated and monitored. Various detection devices, sensors, and software have been developed to monitor battery parameters, including voltage, current, temperature, and charge and discharge curve analysis, to detect internal short circuits and interrupt the charging process. Internal short-circuit detection based on direct characteristics is straightforward to implement and enables online monitoring of internal short circuits in batteries. However, it struggles to detect early signs of such faults accurately and makes it difficult to quantify their severity [7].

Based on the risk - causes - consequences - prevention measures structure and the technical conditions and health and safety requirements applicable to EV charging station maintenance activities, a decision support system for preventing risks associated with disasters and means of protecting people in order to prevent risks in the maintenance activity of EV charging stations [2, 3]. Figure 3 shows some of the input data specific to maintenance work – the input page of the general decision support system (DSS).

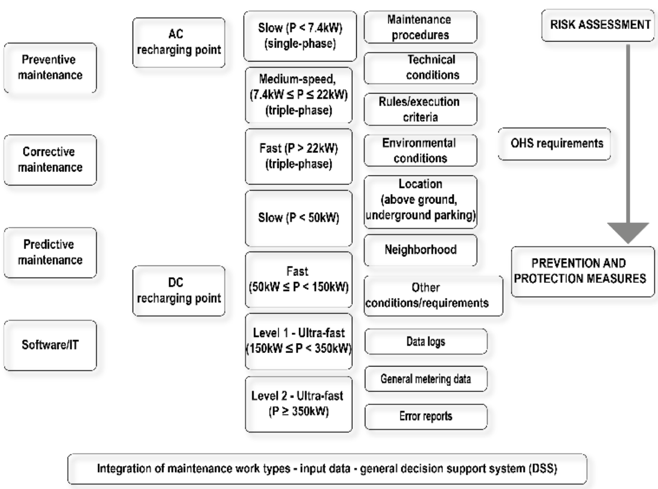

Fig. 3. Integration of maintenance work types - input data - general decision support system (DSS).

The Decision Support System (DSS) is an IT tool used to support decision-making processes. It has been tested and implemented to prevent technological risks, occupational accidents, and illnesses in the maintenance activities of EV charging infrastructure [2, 3]. By incorporating input data, the DSS enables the efficient planning and organisation of maintenance activities, as well as the reduction or elimination of associated risks. Figure 4 presents the results of a case study on an AC charging station, along with the checklist for preventive maintenance activities, generated based on the input data from the general decision support system (DSS).

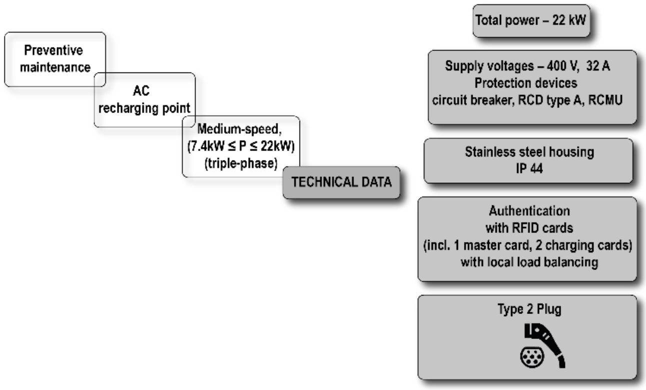

Fig. 4. Case study on an alternating current charging station and preventive maintenance checklist – general decision support system (DSS)

The control of exposure to hazards in the workplace is crucial for protecting workers [8]. The identification of risks and hazards, their prioritisation, the establishment and analysis of causes to propose and adopt the most effective prevention measures, and the establishment and performance of technical and safety checks are defining elements in achieving the objective of zero work accidents in maintenance activities.

Thus, in addition to the risk of electrocution generated by the electrical part of the recharging station, we also considered the risks of fire and explosion associated with the electric battery, mechanical risks, ergonomic risks, musculoskeletal disorders, and the stress specific to the maintenance activity.

Accidental releases of toxic/flammable/ explosive substances can have serious consequences for workers or the neighbouring population, but also the need to identify and evaluate risks of a chemical nature must be taken into account in terms of the impact [9, 10].

The final preventive maintenance report is shown in fig 5. This report is automatically produced when the operator has entered data for all maintenance gangs. The services for EV charging stations maintenance require knowing about several factors related to operation. The operational costs of this kind of equipment are connected to a range of factors including the size of charging station infrastructure as well as the quantity and skills of workers that operate and maintain it.

Preventive maintenance final report

A. **VISUAL EXAMINATION**			OBS
I. Location	1 Zone	☐ presence of gas ☐ presence of flammable materials ☐ presence pf combustible materials ☐ cleaning ☐ moist/water	
	2 Neighborhood	☐ installations (electrical/ overhead power lines, water, gas, etc.) ☐ ongoing works (e.g. construction sites, urban planning works), etc.	
II. Mounting	1 Wall 2 Support/pole 3 Floor 4 Asphalt layer/Tiles/etc.	☐ rigid fixation ☐ damage (cracks, knocks) ☐ cleanliness ☐ other …………………………	
III. Charging station casing	1 Exterior casing	☐ damage (cracks, knocks, bent) ☐ traces of corrosion ☐ traces of rust ☐ cleanliness ☐ missing components (e.g. screws, nuts)	
	2 Access	☐ gasket condition ☐ condition of closing elements	
	3 Interior casing	☐ traces/presence of insects ☐ presence of excess foreign particles ☐ blocked ventilation holes/openings	
IV. Recharging station components	1 Removable parts	☐ missing parts ☐ rigid fixation ☐ damage (cracks, knocks, bent) ☐ traces of rust	
	2 Conections	☐ rigid fixation ☐ insulation condition (cracks, bumps, pinches) ☐ traces of electric arc ☐ ferrules condition (missing, deformed)	
	3 Cable	☐ rigid fixation ☐ insulation condition (cracks, bumps, pinches) ☐ ferrules condition (missing, deformed)	
	4 Plugs/sockets	☐ rigid fixation ☐ insulation condition (cracks, bumps, pinches) ☐ traces of electric arc ☐ ferrules condition (missing, deformed)	
V. Markings	1 Button marking	☐ indentification ☐ clear ☐ visibile	
	2 Labels	☐ missing/damaged ☐ clear ☐ visibile	
	3 Warning/mandatory/ information signs	☐ missing/damaged ☐ clear ☐ visibile	
B. PERIODIC TESTS	1 Operation	☐ functional tests	
	2 Electric	☐ checking electrical insulation of connectors ☐ electrical disconnection system test	
	3 OSH	☐ Charging station electrical power supply installation inspection report no/date…… ☐ Earthing installation inspection report no./date…………………. ☐ Protection connection continuity verification report no./date …………….	

Fig. 5. Preventive maintenance final report

Figure 6 shows a screenshot of the risks generated by proximity to vehicles transportin hazardous substances.

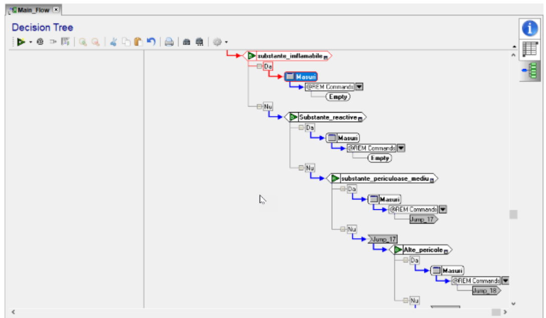

Fig. 6. Integrating identified injury and illness risks into the overall decision support system (DSS) – Knowledge Builder application (screenshot) – simulation

In addition to maintenance activities, operators must also analyse error reports for each electric charging station. Since one of the main features of the Expert System is to integrate data from internal and external sources, it was aimed that in addition to the technical data/characteristics and the data provided from the maintenance process of the EV charging stations, operators should integrate the data from the error reports into analysis to identify recurring defects/errors as easily as possible.

Additionally, through various telephone applications and interconnected platforms, it is possible to ensure easier monitoring of the technical parameters of EV electric battery charging and detect errors and defects more quickly without manually checking logs and comparing them with previous error reports.

Although AI models for electric vehicle charging station maintenance are continually improving, it is essential to acknowledge that many outages still originate from underlying issues, including inadequate monitoring, insufficient 24/7 support teams, or simple human errors. Therefore, AI should be seen as an additional tool in the maintenance activity.

3 Conclusion

In the context of European policies on carbon emissions generated by the vehicle fleet, the development of Romania's EV recharging infrastructure is in full swing. However, there are significant challenges related to equitable coverage across the entire country, especially in rural areas and, therefore, challenges related to facilitating long-distance travel. The development of EV recharging infrastructure also involves the development of their maintenance activities.

Although the number of fires generated by EV electric batteries is considered small, the possibility of detecting and quickly extinguishing them is complicated. Such an event would result in significant economic losses for electric vehicle owners and system operators and may also cause casualties. Proper maintenance of electric vehicle recharging stations, including maintaining correct functioning and recharging at optimal parameters, significantly decreases the probability of these events occurring.

Looking ahead, the work will continue with the integration of advanced predictive maintenance (with AI and IoT) by identifying and analyzing remote diagnostic practices and methods and their effectiveness as periodic verification tools.

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