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AN ADVANCED METHOD FOR ASSESSING THE SIGNIFICANCE OF CHANGE IN ELECTRIC VEHICLES AS A NEW TOOL FOR SUSTAINABILITY AND OPERATIONAL RELIABILITY

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Abstract:

Safe and reliable implementation of changes in technical, organisational, and operational systems in the transport sector is essential for introducing innovations aligned with sustainable development goals. The method currently used (Chruzik et al., 2021) is based on expert analysis, dependency matrices, and quantitative risk assessment. While it is widely applied, it still leaves room for interpretive subjectivity. The extension proposed in this article builds on this foundation by incorporating updated risk registers and enhanced evaluation criteria, with a particular emphasis on operational reliability and sustainability. This approach improves the objectivity and reproducibility of assessments regarding the significance of implemented changes. The objective of this paper is to develop and demonstrate an advanced method for assessing the significance of changes in transport systems, with a particular focus on operational reliability, safety, and sustainability. A key novelty is the integration of classical FMEA methodology with a system-oriented framework, introducing parameters of uncertainty and consequence. The combination of these two factors forms a basis for a more structured and transparent risk matrix. The proposed method was applied to evaluate the significance of change associated with integrating electric vehicles (EVs) into urban traffic systems. While the analysis identified new risk areas—especially related to secondary battery fires—the overall change was assessed as non-significant. Nonetheless, it was recognised that this transformation requires the implementation of preventive measures and updated operational procedures to manage emerging risks. This enhanced method strengthens decision-making processes by improving the clarity and credibility of change assessments in the transport sector. Its flexibility allows it to be adapted to other technological innovations, enabling a balanced consideration of operational safety, technical feasibility, and long-term sustainability. By incorporating risk-based criteria alongside sustainability indicators, the method supports a more holistic understanding of how change impacts complex systems. As transport systems continue to evolve in response to technological advancements and environmental priorities, this approach offers a practical and robust tool for guiding strategic implementation. It ensures that changes are introduced with a clear understanding of associated risks and opportunities, aligning technological development with broader goals of operational reliability and sustainable mobility.

Keywords: *electromobility; transport; safety; significance of change; sustainability*

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1. Introduction

Safe and reliable implementation of changes in technical, organisational, and operational systems in the energy industry is a key element for ensuring the stability of energy supply, environmental protection, and the availability of modern infrastructure for society (International Energy Agency, 2023; International Organization for Standardization, 2018). Currently, the list of changes being implemented in the industry is extensive and mainly associated with achieving sustainability and ensuring reliable system operation.

A significant transformation is occurring in the energy sector, moving away from traditional, often high-emission methods of energy production and consumption, such as fossil fuel combustion, towards cleaner energy sources including solar, wind, and hydropower. These changes contribute to reducing environmental impacts while enhancing the security and reliability of supply. Investments in new technologies and energy-saving measures enable the industry to mitigate the risks of energy supply disruptions and improve the operational reliability of its systems.

Diversification of energy sources, involving the use of various fuels and technologies, helps to reduce the risks associated with dependence on a single energy source, ultimately increasing system resilience. The introduction of modern information technologies and advanced monitoring systems enables more effective management of power grids, rapid fault detection, and timely responses to failures, thereby enhancing the safety and operational reliability of energy supply.

Furthermore, the establishment of appropriate legal and regulatory frameworks promotes energy security, operational reliability, and environmental protection by encouraging investments in innovative technologies, improving energy efficiency, and ensuring market stability. These frameworks are driving the implementation of multiple changes across the industry. However, achieving higher safety and operational reliability demands an integrated approach, considering technological and methodological aspects, as well as cooperation among diverse stakeholders, including energy companies, regulatory bodies, and civil society.

Assessing the significance of changes within transport and energy systems is therefore an essential tool for ensuring that new solutions are implemented prudently, without compromising operational reliability. The methodology proposed by Chruzik et al. (2021) is based on expert competence but leaves room for multiple interpretations. The model presented in this article aims to enhance the objectivity and robustness of assessments by basing evaluations on existing lists of risk areas relevant to technical facilities and processes. The objective of this study is to develop and validate a more structured and objective method for assessing the significance of changes in transport systems. The proposed model enhances the robustness of assessments by integrating risk registers, sustainability indicators, and structured evaluation criteria. Its applicability is demonstrated through the case study of integrating electric vehicles into urban traffic flows. This approach supports improvements in operational reliability and the objectivity of analyses related to implementing change.

2. Literature Review

The methodologies currently employed in the transportation industry rely predominantly on qualitative analysis rather than on quantitative tools for assessing the significance of changes. The literature concerning the impact of changes in software engineering and technical systems is extensive and multifaceted, encompassing diverse approaches and methodologies reflected in numerous scientific publications.

A significant area of research focuses on techniques for analysing the impact of requirements changes on systems, underlining their importance for effective project management and adaptation of technical architectures. Sun et al. (2010) describe methods for change impact analysis based on a taxonomy of change types, which is essential for identifying potential issues and risks associated with implementing changes in complex systems. Similarly, engineering design methodologies for evaluating the consequences of changes are discussed by Eckert et al. (2004), who emphasize the critical role of these analyses in minimising negative impacts on technical projects.

Comprehensive overviews of practices in engineering and technology management are provided by authors such as Morse et al. (2019) and Kossiakoff et al. (2011), who examine various methods for assessing and implementing changes in technical systems, though often at a general or conceptual level.

A separate group of studies concentrates on critical systems, where risk analysis and the evaluation of changes are paramount for maintaining safety and operational continuity. Borg et al. (2017) centre their research on risk analysis and change evaluation in safety-critical systems, highlighting methods designed to prevent potential threats. Bock (2001) evaluates the benefits and risks associated with research and development within systems engineering, which is significant when adopting new technologies. Stamatis (2019) presents the Failure Mode and Effects Analysis (FMEA) method as an essential tool for predicting and preventing potential failures in technical systems by systematically identifying possible failure modes and assessing their impacts.

The human and organisational dimensions of change management are also extensively addressed in the literature. Beckman et al. (2007) present an analytical approach to change management in global technical systems, discussing methodologies for impact assessment in large corporate environments. Authors such as Jeffrey et al. (2012), Smith et al. (2014), and Palmer (2003) explore human factors, particularly resistance to change, and propose strategies, tools, and techniques to support effective implementation processes. Leveson (2012) advocates for systems thinking as an essential perspective for managing safety during technical changes, underscoring the necessity for holistic, systemic analysis. Brown (2009) analyses design thinking as a creative and innovative approach to managing technical changes and fostering new solutions within organisations.

The economic and organisational impacts of technological change are also widely discussed. Adeyeye (2014) investigates how technological innovations influence organisational structures and performance, offering methodologies for practical assessment and adaptation.

Additionally, a valuable contribution to the literature comes from case studies and best practices. Authors such as Cusick (2018), Esplana (2024), and Fleming (2008) offer practical perspectives on change management from both organisational and engineering viewpoints. These studies provide detailed examples and strategies that highlight the challenges and solutions involved in implementing significant changes in complex systems.

Each of these publications offers critical insights and diverse perspectives on analysing and managing the impacts of changes in technical contexts. They integrate theories, practical tools, and methodologies necessary for effective adaptation in a dynamic engineering environment.

In summary, the review of key publications on change impact assessment identifies several evaluation trends commonly applied across engineering and technical disciplines:

1. Change Impact Analysis (CIA): Focuses on understanding the effects of changes within a system by analysing interdependencies among individual components. This approach helps identify potential issues and risks associated with implementing changes.
2. Business Impact Analysis (BIA): Examines how changes will affect critical business processes and operations. BIA aids in identifying which systems and processes may be disrupted and the potential consequences for the organisation.
3. Value Analysis: Evaluates the benefits and costs of implementing changes, facilitating comparison among various options to select the most effective approach to change implementation.
4. System Criticality: Assesses whether changes impact systems or components deemed critical for safety, performance, or operational continuity. Critical systems generally require more rigorous evaluation and approval processes.
5. Modelling and Simulation: Employs computer models and simulations to predict the effects of changes on system functionality and performance, enabling evaluation of different scenarios before implementation.
6. Technical Qualification and Validation: Involves conducting tests to confirm that changes are technically sound and do not negatively affect other systems or components. This may include unit, integration, and functional testing.
7. Change Categorisation: Classifies changes as minor, medium, or major based on criteria such as scope, number of affected components, required resources, and time frame, which helps determine the appropriate level of oversight and change management procedures.
8. Compliance Review: Evaluates whether proposed changes comply with applicable standards, regulations, and organisational policies, ensuring that no non-conformities are

introduced that could breach regulatory requirements.

9. Risk Assessment: Involves identifying, evaluating, and prioritising risks associated with implementing changes and developing strategies to manage these risks. This process assesses how a change might influence existing risks or introduce new hazards, providing insights into the significance of the change from a safety perspective.

The latter has been utilized in the method proposed in the publication for assessing the significance of change, allowing for an objective evaluation of the criteria required in the industry (Table 1).

In recent years, increasing attention has been given in the literature to the need for standardized and objective methods of assessing the significance of change in transport systems, particularly in the railway and aviation sectors. The report by the European Union Agency for Railways (2024) indicates that while the EU has established formal frameworks for risk assessment (CSM RA), there is still a lack of clearly defined models that enable comprehensive classification of technical, organizational, or environmental changes. In practice, mostly partial approaches are applied—based on expert judgment or incident data—which limits the comparability and repeatability of outcomes.

Similar conclusions are drawn by Berggren et al. (2023), who examined the impact of climate change on railway infrastructure in Sweden and highlighted the necessity of integrating operational reliability assessments with long-term environmental risk analysis. Although engineering tools and meteorological data were used, no unambiguous model for classifying a change as significant or non-significant was proposed—the conclusions remain fragmented and context-dependent.

Likewise, Chen and Hall (2021), analyzing the implementation of high-speed rail in Europe, emphasized the wide-reaching effects of infrastructure changes, including not only technical aspects but also socioeconomic system impacts. However, this study also lacked a formal classification of change significance and instead described its consequences through comparative analysis.

Additionally, Janic and Zanin (2025) explored the consequences of shifting passenger transport from air to rail in the context of European climate policy. Their study assessed how such measures influence infrastructure and operations, yet again applying scenario analysis without a precise classification of the significance level of the change introduced.

On a global scale, the IPCC (2022) report stresses that transport system transformation requires evaluation not only of the technical feasibility of change, but also of its impact on operational reliability, social readiness, and long-term sustainability goals. Here too, the approach remains descriptive, without clearly defined procedures for assessing change significance in a systemic context.

Although numerous examples of change impact analysis exist in the literature, a consistent and unified model for clearly evaluating the significance of such changes is still lacking. Fragmented approaches dominate, tailored to specific local contexts or individual technologies. The method proposed in this study directly addresses this gap by offering a more structured and objective approach to classifying the significance of changes in transport systems.

3. Significance of Change Assessment. Materials and Methods

By analysing the legal requirements and acceptable practices concerning risk management and assessing the significance of modal shift, common and extreme assessment criteria used for further research can be identified. Legal requirements are summarised in Table 1. The most detailed requirements are contained in documents published for rail transport, and their scope overlaps with other requirements identified in different transport modes (Bradford, 2018; European Parliament, 2018; European Union, 2013; IMO, 2014; International Civil Aviation Organization, 2009; Office of Rail Transport, 2014; The Prime Minister of Poland, 2018). The only more stringent criterion applies to risk assessment whenever it is justified, and not only when a change is considered significant. For research on the introduction of change to the standard model, a methodology derived from rail transport with an extension of the risk management process is applied (Chruzik et al., 2021).

Table 1. Legal requirements for risk management and the assessment of the significance of change in transport.

Air Transport	Rail Transport	Maritime Transport	Road Transport
Critical assessment of systems and activities	Effects of system failure	-	-
Stability of systems and operating environments	Complexity of the change Monitoring Reversibility of the change	-	-
Operation in the past	Innovation	-	-
Accumulation of changes	Additionality	-	-
Risk assessment whenever a risk occurs	Risk assessment in case of a significant change	Risk assessment for system changes as well	Limited risk assessment

In line with the rules applicable to transport, assessing the significance of change begins with the initial definition of the system to be changed. This includes a description of the technical system's characteristics and basic parameters and the functions and elements of the system that are subject to the change (technical, organisational, and environmental).

The next step is the selection of criteria (derived from the requirements for rail transport):

- effects of system failure: a credible worst-case scenario in case of the failure of the system under assessment, considering the existence of safety barriers outside the system (F),
- innovation used to bring about the change—this criterion covers innovations that affect both the entire transport industry and the organisation implementing the change (I),
- the complexity of the change (C),
- monitoring: inability to monitor the change introduced throughout the entire life-cycle of the system and to carry out appropriate interventions (M),
- reversibility of the change: inability to return to the system from before the change (R),
- additionality: assessment of the significance of the change, considering all recent safety-related changes to the system under assessment that were not assessed as significant (A).

The first stage of the analysis proposed in the publication is to define the system before the change is introduced. The following should be defined:

- system objective (intended purpose),
- system functions and elements, where relevant (including human, technical and operational elements),
- system boundary, including other interacting systems,
- physical (interacting systems) and functional (functional input and output) interfaces,
- system environment (e.g. energy and thermal flow, shocks, vibrations, electromagnetic interference, operational use),
- existing safety measures and definition of the safety requirements identified by the risk assessment process (at the necessary relevant stages).

According to the new model for the described system, prior to the change, the assigned risk areas (based on the existing lists of risks) for technical objects or processes should be identified by groups of criteria (subsections 1–6). In the next step, following analysis of the target system after the change, the risk ranking should be re-examined, and new risk areas should be identified with priority assignment.

Ultimately, the basis for assessing the significance of a change is to analyse and discuss the conditions of project implementation and to look for sources of potential risks that may occur during the process, affecting their quality and the possibility of human error, as well as the potential impact of these changes on the system after their implementation. The procedure is illustrated in Figure 1.

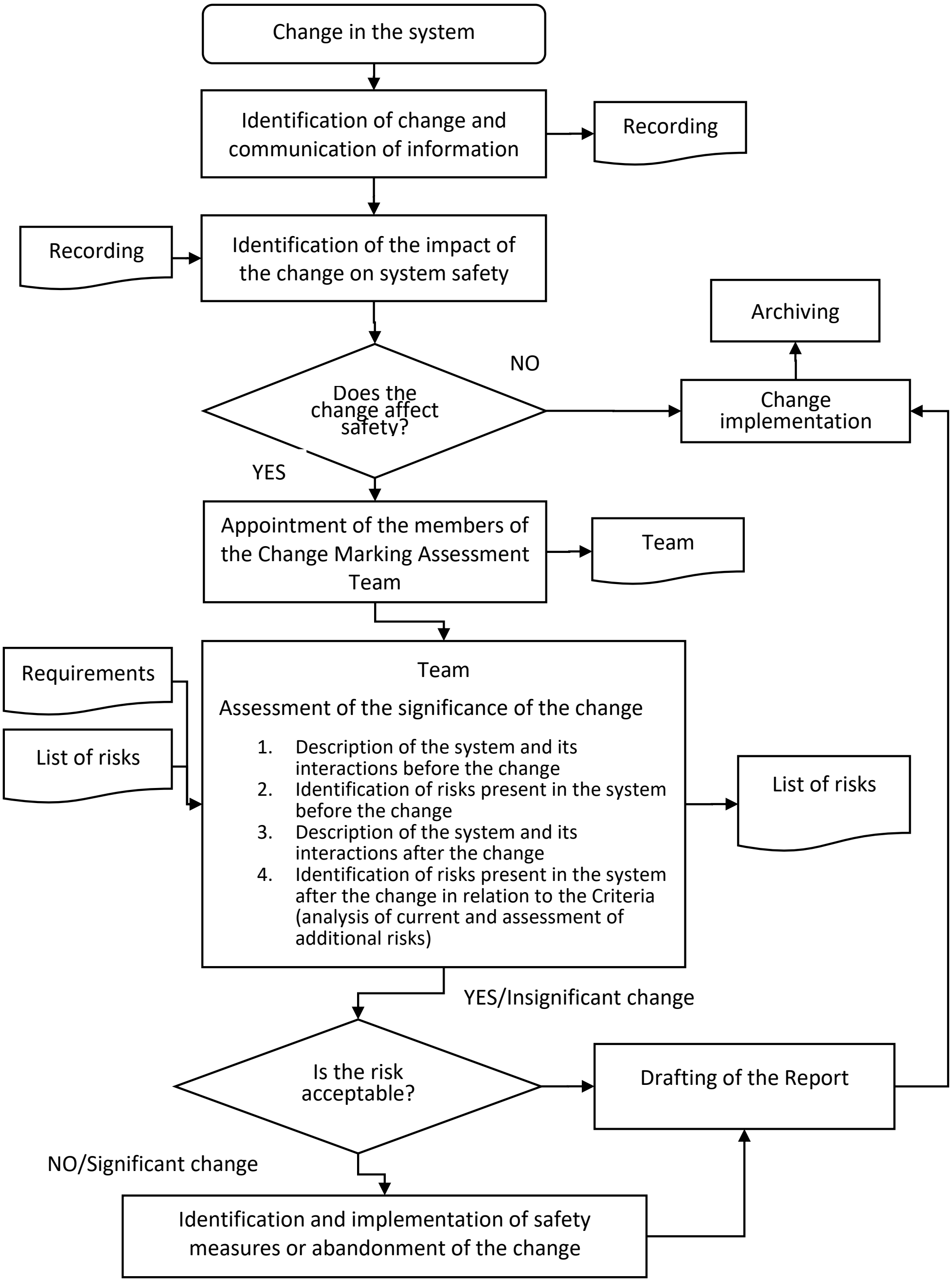

Fig. 1. Change significance assessment procedure

4. Results

The subject of the study is the process of operating electric vehicles (EVs) in the urban areas and analysis of the change associated with the integration of vehicles with non-conventional energy sources into traffic flows. This change relates to the process of vehicle use and maintenance and its impact on road transport safety. Before the change, the system relied on conventional energy sources used in road vehicles. The completed analysis of the lists of risks concerned internal combustion and liquefied natural gas-powered vehicles. Within the survey of risk areas, their risk rankings clearly fit within the acceptable or tolerable range. This is because the initial research involved designs commonly found on the market with a validated maintenance process. Examples of risk analysis are presented in Table 2. The product of the probability (P), risk detection capability (D) and consequences (C) according to the FMEA (Failure Mode and Effects Analysis) applied to the analysed risks enabled determining their Risk Priority Number (RPN).

The risks identified in the study with the highest RPN for internal combustion vehicles were seal failure, fuel filter failure, and fuel- line hose damage. All the listed risks had a value of 125, resulting in them being ranked as tolerable, requiring improvement. To prevent these risks from occurring, spare parts that meet the manufacturer's specifications should be used and the vehicle should be regularly serviced at an authorised service centre, so that qualified persons carry out servicing and repair operations with due diligence using dedicated tools.

The risk with the highest RPN for LPG (Liquefied Petroleum Gas)-powered vehicles is controller failure, resulting in intermittent operation of injectors, and sensor damage. The vehicle user may experience discomfort due to the perceived jerking of the car. The value of this risk is 105, resulting in it being ranked at an acceptable level. To avoid controller failure, the vehicle should be serviced regularly and special attention should be paid to the car’s operation.

All the risks analysed fall within the acceptable (1–120) or tolerable (121–150) limits, according to the applied FMEA methodology (Chruzik et al., 2021). The system after the change is traffic with electric vehicles included. The risk present for all the energy sources analysed is explosion – it assumes certain values for all the energy sources analysed in the acceptable ranking range, but the values for electric vehicles are the highest of the energy sources analysed, namely – 30 for explosion during charging. In order to reduce this risk area, spare parts that meet the manufacturer's specifications should be used and the vehicle should be serviced regularly at an authorised service centre.

The risks with the highest priority number (R) for electric EVs are lack of specialised servicing facilities, fire during an incident, and secondary fire. The first two risks listed have the value of 120 and 70, respectively, ranking them as acceptable, but the lack of specialised service facilities is at the upper end of the range. In order to reduce the risk incidence, it is important to obtain information from the vendor regarding the verified and authorised service points when purchasing an electric car. The risk currently identified at a tolerable level (R=144) is secondary fire. This refers to a situation after a primary fire resulting from an accident or collision has been extinguished. The essential parts of an electric car's battery are either individual cells or separately insulated cell modules, each with a stored charge.

Table 2. Selected risks in the operation of internal combustion vehicles

	Risk	Drive type	P	D	C	RPN
1.	Engine seal failure	internal combustion	5	5	5	125
2.	Fuel filter failure	internal combustion	5	5	5	125
3.	Injector controller failure	gas	5	3	7	105
4.	Damage to fuel lines	internal combustion	4	5	5	100
5.	Leaks in the LPG system	gas	3	4	7	84
6.	Incorrectly configured gas installation	gas	5	3	5	75
7.	Damage to the fuel pressure regulator hose inlet	internal combustion	3	2	9	54
8.	Damage to the installation caused by mechanical impact	gas	3	2	9	54
9.	Fuel tank leaks	internal combustion	1	5	8	40
10.	Corrosion of the fuel tank	internal combustion	2	2	9	36

Heat energy is released from further cells that have been damaged but have not yet combusted, resulting in further fires (Sun et al., 2020; Zhang et al., 2022). Due to the relatively short lifespan of this type of vehicle, there is a lack of specialised procedures related to securing the scene of the accident and the vehicle itself. This implies a high probability and impact of the risk with a relatively high detection rate. This value is averaged in the publication and is strictly dependent on the experience of the emergency services in each area. Highly industrialised countries with a high proportion of electric cars in the total number of vehicles on the roads have already developed specific procedures for handling these issues.

The selected Risk Priority Number (RPN) values for hazard areas in combustion and electric vehicles are illustrated in Figure 2.

Table 3. Selected risks in the operation of electric vehicles

	Risk	Criterion	P	D	C	RPN
1.	Secondary fire	I	6	3	8	144
2.	Lack of specialised repair shops	A	6	4	5	120
3.	Fire during an accident	F	7	1	10	70
4.	All equipment powered from the battery	C	3	3	5	45
5.	Short vehicle range	I	7	1	6	42
6.	High vulnerability of batteries to negative temperatures	C	4	3	3	36
7.	Explosion during charging	A	3	1	10	30
8.	Rapid battery depletion	C	4	1	6	24
9.	Battery damage as a result of an accident	F	2	1	10	20
10.	Spontaneous combustion	F	1	1	10	10
11.	Explosion	F	1	1	10	10

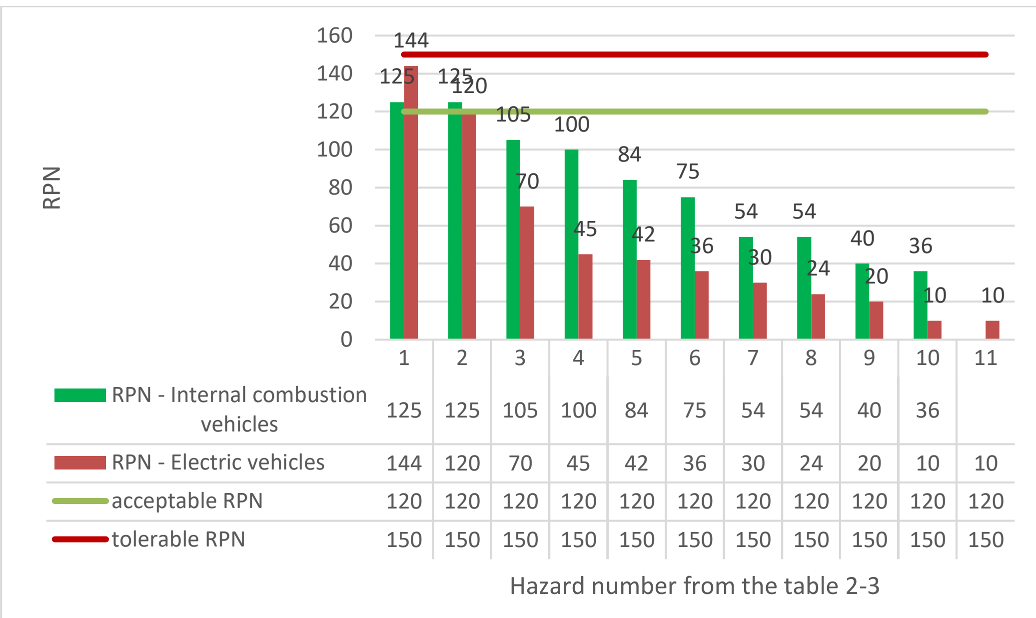

Fig. 2. Selected Risk Priority Number (RPN) values for key hazard areas in combustion and electric vehicles

Based on the risk analysis, the first criterion analysed was additionality — the change was considered to have no impact on the security of the implementation and operation of the solution. Following the guidelines of (Chruzik et al., 2021), the innovation and complexity criteria were combined into a single 'uncertainty' parameter, allowing a matrix to be constructed, consisting of the 'uncertainty' parameters and the consequences of system failure (modelled after the risk matrix). For the overall process, uncertainty was estimated as low (=2) due to the following factors:

- innovativeness of the system after the change — in relation to the baseline, it should still be considered innovative and non-standard, but increasingly common in the marketplace
- the complexity of the change must be described as high, for instance, due to the instability of battery use under different climatic conditions.
- the team estimated the Impact (of a failure in the system area), i.e. the plausible worst-case scenario in the event of a failure of the assessed system, taking into account risk mitigation measures, as marginal = '2' due to the following factors:
- the worst-case scenario for a breakdown in the operation of electric vehicles is a secondary fire resulting from a damaged battery. This scenario has changed as a result of improved emergency- service procedures resulting from increased experience in handling post-accident situations.

The consequence of multiplying the weights assigned to the Uncertainty (2) and Impact (2) criteria is a value of '4'. The team decided that, in terms of monitoring and reversibility, the change does not have a significant impact on safety. Using the described methodology to assess the significance of the change, the change resulting from the introduction of electric vehicles into urban traffic flows was determined to be insignificant.

The extended dataset covered five propulsion categories—combustion (ICE), gas/LPG, hybrid, battery-electric, and hydrogen—with structured FMEA-based scoring (P: probability, D: detectability, S: severity) and Risk Priority Number (R) calculations across detailed hazard registers. For ICE vehicles, the dominant risks were fuel-system leakages (e.g., injection pump O-ring failure, fuel filter housing failure, push-fit hose issues), repeatedly reaching R = 125 and thus requiring improvement, whereas explosion and spontaneous ignition remained very low (R = 8–10) in the analysed scenarios. For LPG systems, characteristic hazards included controller failures causing injector interruptions (R = 105) and installation leaks (R = 84), with rare but credible valve leak/explosion edge cases scored low due to low probability despite high severity. Electric vehicles exhibited a distinct risk profile: alongside acceptable levels for most items, the secondary battery fire emerged as the highest single risk in the dataset (example scoring up to R = 280 in severe conditions), followed by lack of specialised service facilities (often R ≈ 120) and fire during an incident (R ≈ 70). Hybrid vehicles combined ICE-type fuel hazards (multiple entries at R = 125) with battery-related items of lower or moderate R, reflecting their dual architecture. In hydrogen vehicles, acute infrastructure/operational availability risks were prominent—e.g., lack of refuelling stations (R = 90)—while intrinsic fire/explosion items were scored low in probability in the assessed baseline scenario set. Across all propulsion types, shared hazards included: (i) energy storage/transfer failures (fuel or gas leaks; battery damage), (ii) maintenance/configuration deficiencies (e.g., poorly configured LPG systems; inadequate EV servicing capacity), and (iii) rare but high-severity events with low probability (explosions). Propulsion-specific hazards were most visible for EVs (secondary fires), LPG (controller/installation faults), and hydrogen (refuelling infrastructure scarcity), enabling clear differentiation and prioritisation. Methodologically, the unified scoring and risk-register approach produced internally consistent rankings (e.g., repeated R = 125 for fuel-system failures across ICE/hybrids; markedly higher R for EV secondary fire), which corroborates the method's sensitivity to both technology-invariant and technology-specific risk drivers and supports like-for-like comparison of change significance across technologies.

Beyond road transport, the method was applied in rail during the Euroterminal Sławków siding connection and terminal modernisation analysis. There, the team identified and re-scored hazards before and after the change, mapped them to Article 3 criteria of Commission Implementing Regulation (EU) 402/2013, and used established acceptance thresholds to classify significance and derive targeted mitigations (e.g., requirement for a signalling protection design ensuring control from CSR-1, updates to station technical regulations, staff training). This application demonstrated systematic hazard identification, objective thresholding, and actionable recommendations under a regulated framework, further confirming the method's generalisability and effectiveness.

5. Discussion

The study demonstrates that integrating electric vehicles (EVs) into urban traffic systems is highly desirable from a sustainability and environmental perspective. However, it also poses unique risks, primarily related to battery technology. In particular, the phenomenon of secondary fires, which may occur after the initial suppression of a fire incident due to residual heat from damaged battery cells, was identified as the most significant hazard, reflected in a high Risk Priority Number (RPN). These findings align with the observations reported by Sun et al. (2020) and Zhang et al. (2022), who emphasize the critical role of battery safety in the deployment of electric vehicles.

Compared to earlier methodologies, such as those proposed by Chruzik et al. (2021), the approach presented in this study introduces a more objective and quantitative framework for assessing the significance of changes in technical systems. While the traditional approach relied heavily on expert opinions and qualitative assessments, the proposed model integrates updated risk registers and more structured evaluation criteria. This enhances both the transparency and reproducibility of the assessment process, reducing subjective biases and increasing confidence in the results.

Moreover, the proposed method offers advantages over techniques like Failure Mode and Effects Analysis (FMEA) described by Stamatis (2019). Although FMEA is valuable for systematically identifying potential failure modes, it does not always account for broader organisational and operational implications of change, nor for sustainability factors. The method presented here bridges this gap by incorporating sustainability indicators and focusing not only on technical risks but also on social and economic impacts, which is crucial for modern transport systems undergoing rapid transformation towards green mobility.

The method for assessing the significance of change has also been successfully applied in other areas of transport, confirming its universality and effectiveness. Studies conducted for different types of propulsion systems – from combustion and gas-powered vehicles, through hybrids, to electric and hydrogen-powered vehicles – demonstrated that, thanks to a unified approach, it is possible to compare risk levels and identify the most critical hazards, such as secondary battery fires in electric vehicles or LPG system failures. In the railway sector, the method was applied in the analysis of terminal infrastructure modernization in Sławków, where it enabled systematic hazard identification and objective determination of risk acceptance thresholds in line with Regulation 402/2013. The results of these applications confirm that the proposed tool is flexible and can be effectively used in both road and rail transport, supporting decision-making processes and enhancing operational safety in dynamically changing operational environments.

However, despite these benefits, the study has several limitations. Firstly, the methodology has been tested primarily on a single case study related to the integration of electric vehicles into urban traffic flows. Although this is a significant and timely area of investigation, further research is needed to validate the proposed approach across different transport modes and other technological innovations, such as hydrogen-powered vehicles or autonomous transport systems. Secondly, the assessment was conducted based on existing risk registers and expert opinions, and while this ensures practical relevance, it may also introduce region-specific biases that limit generalisability. Additionally, the dynamic nature of technological development in electromobility means that risk factors may evolve rapidly, necessitating continuous updates of the assessment criteria and risk databases.

From a practical perspective, the proposed methodology can support decision-makers, engineers, and regulatory authorities in evaluating whether planned changes in technical systems, such as the introduction of new vehicle types or energy storage technologies, constitute significant changes that warrant more in-depth analysis and mitigation strategies. The method can also help to prioritise resource allocation for change management projects by distinguishing between minor and significant changes based on quantifiable criteria.

Future research should expand the application of this methodology to other areas of transport and energy systems. Incorporating real-time operational data would further enhance the precision of risk assessments. Furthermore, integrating advanced modelling and simulation tools could enable more detailed analyses of the consequences ts flexibility allows it to be adapted to other technological innovations.of potential failures and support proactive measures to mitigate emerging risks. Finally, exploring how sustainability metrics can be systematically included in change significance assessments will be crucial to ensure that technological innovations contribute not only to operational efficiency but also to long-term environmental and social goals. The presented method provides a robust and flexible tool for assessing the significance of changes in transport systems, supporting both operational safety and sustainable development goals. Its further development and broader application hold significant potential for improving decision-making processes in dynamic and complex technical environments.

6. Conclusions

New and innovative solutions introduced in the electrical industry generate various risks, particularly during their initial phases of operation. Managing safety and operational reliability when implementing such changes is therefore a critical and highly significant task.

The method for assessing the significance of change proposed in this article, which extends the analysis through criteria based on risk areas associated with technical facilities or processes, can enhance evaluations and increase both the objectivity and reliability of results. The analysis of the safe and reliable operation of electric vehicles in metropolitan areas, as presented in this study, is a complex issue that requires consideration of diverse technical, operational, environmental, and human factors. Incorporating criteria based on existing hazard lists enables a more objective and comprehensive quantitative analysis, while also ensuring operational reliability. Sustainability indicators play a key role in evaluating the significance of changes that affect communities or the economy. These indicators encompass social, environmental, and economic dimensions. For instance, assessing the introduction of a new policy or technology requires considering impacts on social sustainability, environmental resilience, long-term operational reliability, and economic sustainability.

In the context of changes such as the implementation of new infrastructure or regulations, cost-benefit analysis becomes a crucial assessment tool. It is essential to consider both short-term and long-term impacts, including sustainability aspects such as effects on ecosystems, local communities, or climate change, as well as implications for operational reliability and overall system performance over time.

The significance of any change can be evaluated in relation to global sustainable development objectives, such as those outlined in the UN's Sustainable Development Agenda (2030 Agenda). Aligning change assessments with these objectives helps determine whether specific innovations contribute meaningfully to progress toward a more sustainable and operationally reliable future.

By integrating these elements, it is possible to conduct a comprehensive assessment of change significance that simultaneously accounts for sustainability, ensures operational reliability, and balances present needs with future demands. The method proposed in this study offers a promising tool for supporting decision-making processes in complex technical environments undergoing dynamic transformation.

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