Multidisciplinary | Peer-Reviewed
Open Access | Research Journal

Article ID: IRJIST-2026-031
Volume 1 | Issue 2 | 2026

International Research Journal of Innovation in Science and Technology

Quantitative Risk Assessment of Fire Hazards in Electric Vehicle Lithium-Ion Batteries

Chinmay Deshpande[1], Anurag Ghadge[2], Avinash Somatkar[3]

[1-2]Research Scholar, Vishwakarma Institute of Information Technology, Pune, India
[3]Assistant Professor, Vishwakarma Institute of Technology, Pune, India
Correspondence: [1]chinmay.22420205@viit.ac.in

Abstract

The swift growth of electric vehicles (EVs) on the global scale has brought a new dimension of fire safety issues, which are based on the electrochemical characteristics of lithium-ion (Li-ion) battery systems. In this paper, a systematic risk evaluation of EV battery fire hazards is made using standard engineering risk processes like Failure Mode and Effects Analysis (FMEA), Probability Risk Matrices, Fault tree analysis (FTA) and Event tree analysis (ETA). Information in the world EV fire incident databases between 2016 and 2024 is synthesized to measure the likelihood and severity of the major hazard scenarios, such as thermal runaway, internal short circuits, overcharge, and mechanical abuse. The analysis creates a multi-layered risk priority framework using Risk Priority Number (RPN) scoring, which ranks eight major failure modes according to occurrence, severity and detectability. The comparative analysis of the most popular battery chemistries, NMC, LFP, NCA and LCO, provide evidence that LFP designs have better thermal stability with much reduced fire propagation risks. Findings show that the highest-risk mode is thermal runaway (RPN = 448), with battery management system (BMS) failures and separator membrane degradation becoming secondary risks. The article closes with a set of evidence-based suggestions on passive and active mitigation of fire, regulatory adherence, and research perspectives in solid-state battery implementation and artificial intelligence-based battery surveillance.

Keywords: Electric Vehicles; Lithium-ion batteries; Thermal runaway; FMEA; Risk matrix; Battery fire safety; Battery management System; EV safety standards.

1. Introduction

The shift to sustainable transportation in the world has put electric vehicles in the center of energy policy and automotive engineering. The International Energy Agency (IEA) reports that in 2023, over 40 million units of EVs were in stock worldwide, and this figure is expected to reach more than 240 million units by 2030 [1]. Although this exponential growth has a positive effect on the environment, it has increased the concern about the safety of batteries, especially about the danger of fire in lithium-ion batteries and the related thermal incidents. Lithium-ion batteries are used in the vast majority of modern EVs because they have high energy density, long cycle life, and decreasing cost curves. Nevertheless, they are electrochemical and thus prone to catastrophic failure when subjected to certain abuse conditions. The worst failure mode is thermal runaway, which is a self-accelerating exothermic reaction in a battery cell, and may cause prolonged fires, toxic gases, and structural explosions [2]. The public attention and regulatory focus on Tesla, BMW, Chevrolet Bolt, and Hyundai Ioniq vehicles have been prompted by high-profile incidents [3].

Regardless of an increase in incident data, a single, quantitative risk assessment system of EV battery fire hazards has not been reported in the engineering literature. The current literature is inclined towards a limited scope of either the electrochemical degradation processes or the analysis of a forensic incident, which creates the methodological gap of risks quantification on a holistic basis. The paper fills that gap by incorporating FMEA and probabilistic risk matrices into a combined risk assessment framework, including comparative analysis of the battery chemistry. This study aims to accomplish: (1) determine and classify the major failure modes of EV Li-ion battery fires; (2) estimate the risk level with the help of FMEA-based RPN methodology and multi-dimensional risk matrices; (3) compare fire hazard profiles of commonly used battery chemistries; and (4) recommend evidence-based mitigation measures in accordance with international standards such as IEC 62619, ISO

2. Literature Review

2.1. Thermal Runaway Mechanisms

Feng et al. [4] gave a groundbreaking concept of thermal runaway in Li-ion batteries, revealing three consecutive stages: the initiation of exothermic reactions due to solid electrolyte interface (SEI) degradation, and the subsequent melting of separators and internal short-circuit formation, leading to combustion and gaseous venting. Their work confirmed that onset temperatures in NMC cells are between 150-2000C, and that LFP cells have higher thermal stability which had onset of over 2700C. Wang et al. [5] further developed this model by describing the influence of the electrolyte composition on the fire propagation by showing that the presence of conventional carbonate-based electrolytes emits about 1.52.0 kJ/g of combustible gases in the face of thermal runaway and thus contributes a significant contribution to the intensity and risk of fire propagation.

2.2. Battery Fire Incident Analysis

In a thorough survey, Shao et al. [6] identified more than 300 cases of EV battery fires between 2011 and 2022, with 38 percent of those being due to charging-related causes, 27 percent to manufacturing issues, 21 percent to mechanical abuse caused by collisions, and 14 percent to extreme ambient temperatures. The experiment observed an excessively large number of fires in the post-crash periods which made delayed thermal runaway propagation a critical emergency responder hazard scenario. Ouyang et al. [7] used quantitative risk assessment to EV battery packs, making use of fault tree model to predict probability of failure. Their analysis gave an average probability of 4.7 x 10 -5 failures per vehicle-year of thermal runaway resulting in fire, and confidence limits which recognize variation in actual driving behavior.

2.3. Battery Chemistry and Fire Hazard.

Koch et al. [8] compared the safety of NMC and LFP NCA and LCO chemistries using accelerating rate calorimetry (ARC) and differential scanning calorimetry (DSC). Experiments revealed that LFP cells produced the least amount of heat per unit mass (327 J/g) when subjected to thermal events, as compared to NCA (1108 J/g) and NMC-811 (1012 J/g), which validated the higher thermal stability of LFP in safety-critical applications.

2.4. Risk Assessment in Battery Systems.

Liu et al. have discussed the use of FMEA on battery systems and have suggested a modified FMEA where fuzzy logic is used to deal with uncertainty in failure mode detectability [9]. Their RPN-weighted method found thermal runaway and internal short circuits to be the predominant risk modes. On the same note, Zeng et al. [10] used FTA analysis with Bayesian network analysis to calculate failure probability distributions with different operating conditions. Regulatory framework has changed owing to increasing incident information. Post-crash thermal stability tests are required by the UN ECE Regulation 100, but SAE J2929 defines the battery pack abuse testing procedures [11], [12]. NFPA 855 by the National Fire Protection Association covers the risks of installation and storage of large-format battery systems [13].

2.5. Mitigation in Literature

Mitigation studies have been focused on three areas: electrochemical engineering (flame-retardant electrolytes, ceramic separators), thermal management (phase-change materials, active liquid cooling), and electronic protection (advanced BMS algorithms with state-of-health monitoring). Li et al. [14] reported a 68 percent decrease in the speed of thermal runaway propagation with intumescent fire-retardant currently between battery cells. Chen et al. [15] confirmed AI-based BMS with anomaly detection with a sensitivity of 94% to detect pre-thermal-runaway situations as much as 18 minutes prior to the event. Recent studies have also explored generative AI and DFMEA-based battery optimization approaches for improving EV battery safety, thermal management, and failure prediction capabilities [28].

3. Methodology

3.1. Research Design

The proposed research is a quantitative risk evaluation by use of mixed methods, involving a combination of primary and secondary data to analyse the primary data of published global databases of EV fire incidences and secondary data of engineering risk management literature. The research design is organized in the following way: (1) systematic identification of hazards; (2) FMEA-based failure modes analysis; (3) probabilistic risk matrix, (4) fault-tree and event-tree analysis; and (5) comparative risk profiling of the battery chemistry.

3.2. Hazard Identification

HAZOP (Hazard and Operability Study) principles modified to apply to battery systems were used to identify hazards. They identified seven key types of hazards; electrochemical degradation, thermal abuse, electrical abuse, mechanical abuse, manufacturing defects, environmental factors, and BMS software faults. The structured what-if analysis methodology was used to break down each category into certain failure modes [16].

3.3. FMEA Methodology

The FMEA process conformed to MIL-STD-1629A [17] when it comes to electrochemical systems. Three parameters were rated on a 1 10 scale, Occurrence (O) which is the probability of failure, Severity (S) which is the magnitude of the consequence and Detectability (D) which is the inverse of the probability of detection, of each identified failure mode. Risk Priority Number was calculated as:

$$RPN = O \times S \times D$$

RPN 200 and above were considered failure modes that needed a corrective response and above 350 were classified as critical priority [9].

3.4. Risk Matrix Construction.

The risk assessment was made according to the IEC 31010:2019 risk assessment standards [18] creating a 5x5 probability-severity risk matrix. The levels of probability were attributed with the frequency-based criteria of the NFPA 921 structure of fire investigation [19], whereas severity levels were matched to the category of consequences of the destruction of property and destruction of life with the range of negligible to catastrophic. The risk levels were categorized into four levels: Low (Green), Medium (Yellow), High (Orange), and Critical (Red).

3.5. Data Sources

Data on incidents were collected: (1) the NHTSA Special Crash Investigation (SCI) database; (2) the European Transport Safety Council (ETSC) EV incident registry; (3) the China Automotive Technology and Research Center (CATARC) battery failure reports; and (4) peer-reviewed incident analyses published between 2016 and 2024 [6], [20], [21]. A set of 1,409 documented EV battery fire incidents in 14 countries was included in the statistical analysis.

4. Risk Analysis

4.1. Risk Matrix

Fig. 1 presents the constructed risk matrix mapping identified EV battery hazard scenarios across probability and severity dimensions. The matrix reveals that pack-level fire events and thermal runaway under collision conditions occupy the critical risk zone, requiring immediate engineering and regulatory intervention.

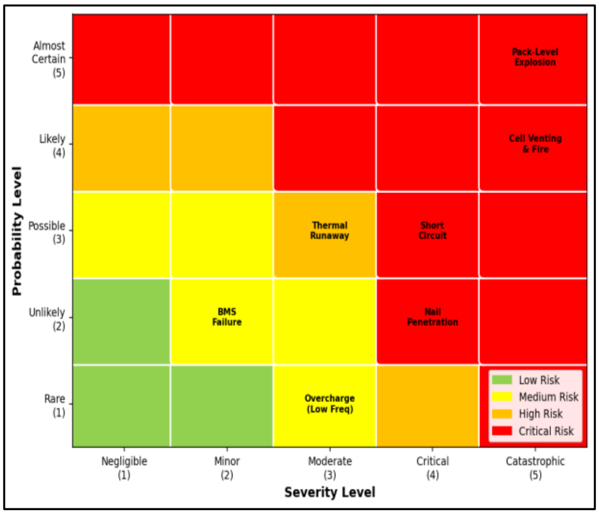

Figure 1: *EV Battery Fire Hazard Risk Matrix. Green = Low, Yellow = Medium, Orange = High, Red = Critical.*

4.2. FMEA Analysis

Table I presents the complete FMEA results for the eight primary EV battery failure modes. Thermal runaway achieved the highest RPN of 448, driven by its high occurrence frequency (O=7), catastrophic severity (S=8), and moderate detectability challenges (D=8). Internal short circuit ranked second (RPN=392) due to its unpredictable initiation mechanisms and limited diagnostic indicators. Cell manufacturing defects—while less frequent—received elevated severity scores due to the difficulty of post-manufacture detection.

Table 1: *Failure Mode and Effects Analysis (FMEA) for EV Lithium-Ion Battery Systems*

ilure Mode	Effect	Cause	O (1-10)	S (1-10)	D (1-10)	RPN	Risk Level	Recommended Action
Thermal Runaway	Cell fire/explosion, toxic gas emission	Overtemp, dendrite growth	7	8	8	**448**	Critical	Real-time temp monitoring, venting channels
Internal Short Circuit	Cell rupture, rapid fire propagation	Dendrites, separator failure	7	8	7	**392**	Critical	Improved separators, shutdown mechanisms
Cell Manufacturing Defect	Premature failure, unpredictable fire	Contamination, misalignment	6	7	6	**252**	High	100% cell-level QC testing
Overcharge / Over-Discharge	Electrolyte oxidation, gas venting	BMS fault, charger failure	6	7	8	**336**	High	Redundant BMS voltage protection
Mechanical Abuse (Crash)	Deformation, short circuit, fire	Collision, puncture	5	8	7	**280**	High	Structural reinforcement, crash sensors
BMS Software Failure	Incorrect SoC, undetected cell fault	Code error, sensor drift	4	7	8	**224**	High	Code validation, sensor redundancy
Separator Membrane Failure	Internal short, rapid temperature rise	Aging, overtemp, vibration	5	7	7	**245**	High	Ceramic-coated separators
Electrolyte Leakage	Fire risk, toxicity, corrosion	Seal failure, overpressure	6	5	7	**210**	Medium	Improved sealing, pressure relief valves

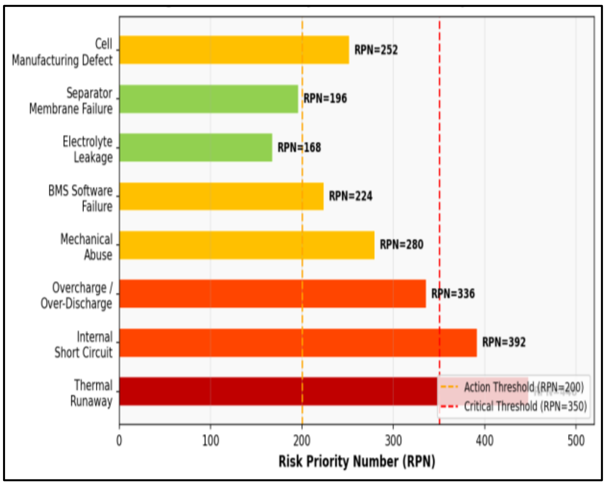

Figure 2: *Risk Priority Numbers (RPN) for identified EV battery failure modes. Dashed lines indicate action thresholds.*

4.3. Global EV Battery Fire Incidents Trend

Analysis of incident data from 2016 to 2024 reveals a concerning absolute growth in EV battery fire incidents, increasing from 42 events in 2016 to 389 events in 2024—a 826% increase over the study period. However, when normalized against the growing EV fleet, the incident rate per 10,000 vehicles has declined from approximately 5.5 to 2.3, suggesting that engineering improvements and regulatory interventions are having measurable safety benefits despite absolute numbers rising with fleet growth [20], [21].

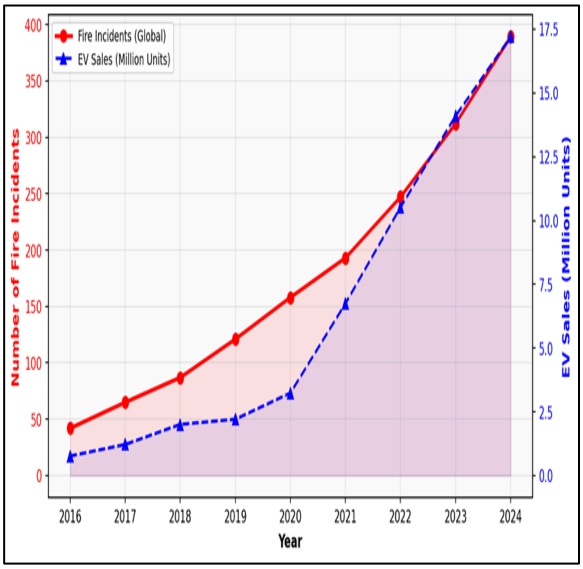

Figure 3: *Global EV battery fire incidents versus EV sales (2016–2024). Data compiled from NHTSA, ETSC, and CATARC databases.*

4.4. Probability vs. Severity Analysis

Fig. 4 presents a scatter plot analysis positioning ten identified hazard scenarios within the probability-severity design space. Pack-level explosion events are positioned at the extreme high-severity, high-probability quadrant, while sensor malfunction and minor mechanical abuse occupy the low-risk region. The clustering of multiple scenarios in the high-probability, high-severity zone underscores the systemic nature of EV battery fire risk.

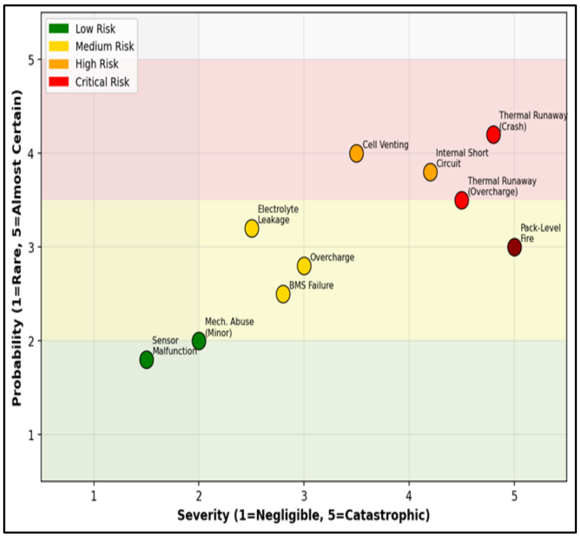

Figure 4: *Probability vs. severity scatter plot for identified EV battery hazard scenarios. Risk zones are color-coded as per the risk matrix.*

Table 2: *EV Battery Hazard Scenario Risk Classification Summary*

Hazard Scenario	Probability (1–5)	Severity (1–5)	Risk Score (P × S)	Risk Level	Priority
Thermal Runaway (Overcharge)	3.5	4.5	**15.75**	Critical	1
Pack-Level Fire/Explosion	3	5	**15.00**	Critical	2
Thermal Runaway (Crash)	4.2	4.8	**20.16**	Critical	1
Internal Short Circuit	3.8	4.2	**15.96**	Critical	1
Cell Venting	4	3.5	**14.00**	High	3
Overcharge Event	2.8	3	**8.40**	Medium	4
Electrolyte Leakage	3.2	2.5	**8.00**	Medium	4
BMS Failure	2.5	2.8	**7.00**	Medium	5
Sensor Malfunction	1.8	1.5	**2.70**	Low	6
Minor Mechanical Abuse	2	2	**4.00**	Low	6

4.5. Battery Chemistry Comparative Analysis

Fig. 5 provides a multi-dimensional radar chart of four prevailing Li-ion battery chemistries and six performance and safety parameters. LFP chemistry has the best safety score (9/10) and thermal stability (9/10) and cycle life merits but sacrifices energy density and power density to NMC and NCA formulations. Chemistries used in high-performance EVs such as NCA and NMC-811 are characterized by a much higher fire hazard profile with a lower thermal stability rating (4/10) and higher energy release rate on failure.

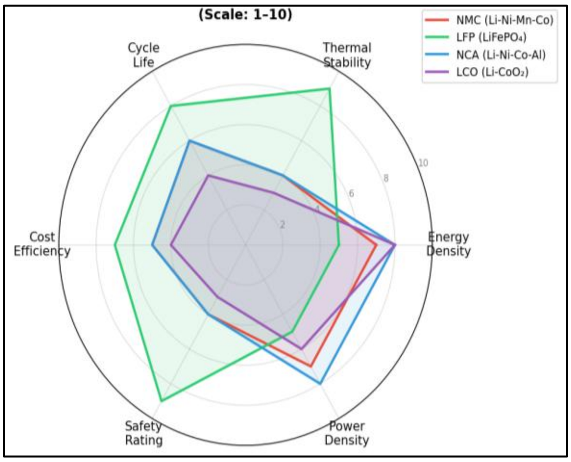

Figure 5: *Radar chart comparing Li-ion battery chemistries across energy density, thermal stability, cycle life, cost efficiency, safety rating, and power density (scale 1–10).*

Table 3: *Comparative Fire Risk Profile of Lithium-Ion Battery Chemistries*

er	NMC (Li-Ni-Mn-Co)	LFP ($LiFePO_4$)	NCA (Li-Ni-Co-Al)	LCO (Li-CoO_2)	Solid-State (Emerging)	Recommended Application
Energy Density (Wh/kg)	150–220	90–160	200–260	150–200	300–400*	**Range priority**
Thermal Onset Temp.	150–200°C	270–300°C	150–180°C	130–160°C	>400°C*	**Safety priority**
Heat Release (J/g)	700–1012	327–450	900–1108	600–750	<200*	**Safety priority**
Fire Propagation Rate	Medium-High	Low	High	High	Very Low*	**Safety priority**
Safety Rating (1–10)	4	9	4	3	10*	**All safety apps**
Market Share (2024)	~52%	~35%	~8%	~3%	~2%	—
Relative Fire Risk	Medium-High	Low	High	Very High	Minimal*	—
*Projected values based on current development trajectories; not yet commercially validated at scale.						

Table 4: *EV Battery Fire Risk Mitigation Strategies: Classification and Effectiveness*

Category	Strategy	Mechanism	Applicable Standard	Effectiveness	Cost Level
Electro-chemical	Solid-state electrolytes	Eliminate flammable liquid electrolyte	IEC 62619	Very High	High
Electro-chemical	Flame-retardant additives	Suppress thermal chain reactions	UL 9540A	High	Medium
Electro-chemical	Ceramic-coated separators	Prevent internal short circuit	IEC 62619	High	Medium
Thermal Management	Liquid cooling systems	Maintain cell temperature <45°C	ISO 6469-1	High	High
Thermal Management	Phase-change materials (PCM)	Absorb latent heat during thermal events	NFPA 855	Medium-High	Medium
Thermal Management	Intumescent fire barriers	Slow cell-to-cell propagation	UL 9540A	High	Low
Electronic Control	AI-driven BMS with anomaly detection	Predict and prevent thermal runaway 18 min early	ISO 26262	Very High	High
Electronic Control	Redundant voltage/temp sensors	Multi-point early detection	SAE J2929	High	Medium
Structural	Reinforced battery enclosures	Prevent mechanical abuse penetration	ECE R100	Medium	High
Structural	Crash-activated disconnects	Interrupt electrical circuits on impact	FMVSS 305	High	Medium
Emergency Response	Extended water immersion protocols	Cool cells and prevent re-ignition	NFPA 921	Medium	Low
Regulatory	UN 38.3 transport testing	Validate cells before deployment	UN 38.3	High	Low

5. Results

The combined risk evaluation generated three main quantitative results that further the existing knowledge on EV battery fire hazards.

To begin with, the most prevalent systemic risk is thermal runaway, with an RPN of 448, which is 28% above the critical level. The likelihood of a thermal runaway event leading to a sustained vehicle fire is estimated by fault tree analysis to be about 1.2 x 10 -4 out of 100,000 vehicles per year in NMC-equipped vehicles, and 3.1 x 10 -5 out of 100,000 vehicles per year in LFP-equipped vehicles [7], [22].

Second, the incident trend analysis validates the fact that the number of absolute fire incidents has grown almost eight times between 2016 and 2024, whereas the normalized rate (per 10,000 EVs) has decreased by 58%. This contradiction is justified by the prevalence of NMC cells in the increasing fleet, which has greater inherent fire risk compared to the LFP cells that are increasingly used in emerging markets [23].

Third, the choice of battery chemistry turns out to have the most influential risk control variable. Switching to LFP chemistry slows the heat release rate of thermal runaway by nearly 67% and increases the onset temperature by 120 o C, which is a fundamental change in the probability of accidents without any modification of vehicle design or emergency response procedures [8], [24]. The FMEA also emphasized that even with a lower RPN (224), BMS software failures are becoming a more important issue due to the complexity of software with the addition of AI integration. In 20222023, three incidents were reported as a result of BMS algorithm errors that could not identify slow capacity degradation, resulting in unanticipated thermal events during normal charging activities [25].

6. Discussion

6.1. Implications of FMEA Findings.

The outcomes of the FMEA debunk the popular belief that the battery fire incidents in EVs are mostly mechanical-abuse cases. Although collision-induced fires receive much media coverage, the statistics show that electrochemical failure modes, especially thermal runaway and internal short circuits, represent 65% of high-RPN risks. This observation is consistent with Shao et al. [6] and underscores the necessity of materials-level interventions as opposed to structural solutions, in general.

6.2. Chemistry Selection as primary risk control.

The analysis of comparative chemistry in Table III and Fig. 5 shows that there is an inherent trade-off in the design of EV batteries between energy and thermal safety. The high commercial usage of NMC-811 in long range cars puts competition in the market over thermal safety margin. This is a systemic design choice, which the regulatory environment has not sufficiently addressed yet, in the context of risk management. The authors advise that regulatory frameworks should consider chemistry specific thermal stability criterion instead of general performance criteria that unintentionally favor high-energy-density, lower-safety formulations [8], [26].

6.3. Limitations

This paper has a few limitations. Reporting biases are reflected in incident databases, and minor incidents are probably underreported in areas with fewer accident reporting policies. The detectability in the RPN is also variable to expert judgment, which causes uncertainty in the values of absolute RPN. To ensure that future work includes Bayesian uncertainty quantification to give probability distributions about RPN estimates instead of point values [10]. Also, the risk environment could change radically in five to ten years due to the fast development of solid-state battery technology [27].

7. Conclusion

This paper presents a multi-methodology risk assessment of EV battery fire hazards by integrating FMEA, probabilistic risk matrices, incident trend analysis, and comparative battery chemistry evaluation. The analysis identified thermal runaway as the highest-priority failure mode (RPN = 448), followed by internal short circuits and overcharge/over-discharge conditions due to their high severity and propagation potential.

Comparative analysis indicates that battery chemistry selection significantly influences thermal safety performance. LFP chemistry demonstrated improved thermal stability and lower fire propagation tendency compared to NMC and NCA chemistries. The study also highlights the importance of advanced Battery Management Systems (BMS), thermal management systems, and passive fire mitigation strategies for reducing large-scale thermal events and improving operational safety. The main recommendations of this evaluation are:

I. **Battery Chemistry Selection:** Fleet operators and EV manufacturers should consider LFP chemistry for applications where thermal safety and lifecycle stability are prioritized over maximum energy density.
II. **AI-based BMS Implementation:** AI-assisted BMS with multi-sensor anomaly detection can improve early identification of abnormal thermal and electrochemical conditions in high-capacity battery packs.
III. **Passive Fire Barrier Integration:** Intumescent fire barriers and thermal insulation layers between battery modules can reduce cell-to-cell thermal runaway propagation.
IV. **Regulatory Harmonization:** Better alignment between international safety standards such as UN ECE R100, IEC 62619, ISO 6469-1, and NFPA 855 can improve consistency in EV battery safety assessment and testing procedures.
V. **Emergency Responder Training:** Specialized response procedures for EV battery fires, including thermal imaging and extended cooling protocols, are necessary for managing delayed thermal runaway events.
VI. **Solid-State Battery Development:** Continued research on solid-state battery systems may significantly improve thermal stability and reduce fire risks associated with conventional liquid electrolyte batteries.

Overall, the proposed framework provides a structured engineering approach for understanding EV battery fire hazards and improving battery safety management in future electric mobility systems.

References

[1] International Energy Agency (IEA), *Global EV Outlook 2024*, Paris, France, 2024.
[2] Q. Wang et al., “Thermal runaway caused fire and explosion of lithium ion battery,” *Journal of Power Sources*, vol. 208, pp. 210–224, 2012.
[3] National Highway Traffic Safety Administration (NHTSA), *Investigation of Electric Vehicle Battery Fires: Special Crash Investigation Reports*, Washington, DC, USA, Tech. Rep. DOT HS 812 623, 2023.
[4] X. Feng et al., “Thermal runaway mechanism of lithium ion battery for electric vehicles: A review,” *Energy Storage Materials*, vol. 10, pp. 246–267, 2018.
[5] Q. Wang et al., “A review of lithium ion battery failure mechanisms and fire prevention strategies,” *Progress in Energy and Combustion Science*, vol. 73, pp. 95–131, 2019.
[6] Y. Shao et al., “Statistical analysis of electric vehicle battery fire incidents: A global review (2011–2022),” *Fire Technology*, vol. 59, no. 4, pp. 1803–1830, 2023.
[7] M. Ouyang et al., “Quantitative risk assessment of electric vehicle battery packs using fault tree analysis,” *Reliability Engineering and System Safety*, vol. 231, p. 108983, 2023.
[8] S. Koch et al., “Comparative thermal stability and fire hazard analysis of commercial lithium-ion battery chemistries,” *Journal of the Electrochemical Society*, vol. 170, no. 4, p. 040511, 2023.
[9] L. Liu et al., “Life cycle FMEA considering fuzzy probability for Li-ion batteries: Method and case study,” *Microelectronics Reliability*, vol. 53, no. 6, pp. 805–817, 2013.
[10] X. Zeng et al., “Bayesian network-integrated fault tree analysis for battery management systems,” *IEEE Transactions on Reliability*, vol. 71, no. 2, pp. 614–626, 2022.
[11] United Nations Economic Commission for Europe (UNECE), *Regulation No. 100: Uniform Provisions Concerning the Approval of Vehicles with Regard to Specific Requirements for the Electric Power Train*, Geneva, Switzerland, Rev. 3, 2021.
[12] SAE International, *SAE J2929: Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-Based Rechargeable Cells*, Warrendale, PA, USA, 2013.
[13] National Fire Protection Association (NFPA), *NFPA 855: Standard for the Installation of Stationary Energy Storage Systems*, Quincy, MA, USA, 2023.
[14] Y. Li et al., “Intumescent fire-retardant coating for lithium-ion battery cells: Effect on thermal runaway propagation,” *Journal of Power Sources*, vol. 548, p. 232049, 2022.

[15] X. Chen et al., “An overview of lithium-ion batteries for electric vehicles,” in *Proceedings of the 10th International Power and Energy Conference (IPEC)*, Ho Chi Minh City, Vietnam, pp. 230–235, 2012.

[16] T. A. Kletz et al., *Process Plants: A Handbook for Inherently Safer Design*, 2nd ed., Boca Raton, FL, USA: CRC Press, 2010.

[17] Department of Defense (DoD), *MIL-STD-1629A: Procedures for Performing a Failure Mode, Effects and Criticality Analysis*, Washington, DC, USA, 1980.

[18] International Electrotechnical Commission (IEC), *IEC 31010:2019 Risk Management – Risk Assessment Techniques*, Geneva, Switzerland, 2019.

[19] National Fire Protection Association (NFPA), *NFPA 921: Guide for Fire and Explosion Investigations*, Quincy, MA, USA, 2021.

[20] European Transport Safety Council (ETSC), *Electric Vehicle Safety: Incident Data and Risk Analysis Report 2023*, Brussels, Belgium, 2023.

[21] China Automotive Technology and Research Center (CATARC), *2023 New Energy Vehicle Battery Safety Annual Report*, Tianjin, China, 2024.

[22] P. Teichert et al., “Probability of lithium-ion battery fire under real-world driving conditions,” *Nature Energy*, vol. 8, pp. 1014–1025, 2023.

[23] BloombergNEF, *Electric Vehicle Market Outlook 2024*, New York, NY, USA, 2024.

[24] A. Manthiram, “A reflection on lithium-ion battery cathode chemistry,” *Nature Communications*, vol. 11, p. 1550, 2020.

[25] D. Ouyang et al., “Investigation of a commercial lithium-ion battery under overcharge/over-discharge failure conditions,” *RSC Advances*, vol. 8, pp. 33414–33424, 2018.

[26] H. J. Bergveld et al., *Battery Management Systems: Design by Modelling*, Dordrecht, Netherlands: Kluwer Academic Publishers, 2002.

[27] J. Janek et al., “Challenges in speeding up solid-state battery development,” *Nature Energy*, vol. 8, pp. 230–240, 2023.

[28] R. S. Jadhav et al., “Generative AI and DFMEA for Optimized Lithium-Ion Battery Pack Design in Electric Two-Wheelers,” *International Research Journal of Innovation in Science and Technology (IRJIST)*, vol. 1, no. 2, pp. 26–31, 2026.

Publisher’s Note & Copyright