ISSN (E) 3007-0376
ISSN (P) 3007-0368

Journal of Advanced Studies in Social Sciences (JASSS)

Vol.4, Issue 2 (July-December 2026)



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Organisational preparedness for lithium ion battery incidents in airport ground handling

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DOI: https://doi.org/10.5281/zenodo.24632235

Abstract

Objective: This review examines how airport ground handling organisations can prepare personnel for incidents involving lithium ion traction batteries in electric ground support equipment. It concentrates on worker instructions, emergency communication and the division of responsibilities between service providers.

Methods: A focused narrative review integrates 39 sources from battery safety research, aviation and occupational guidance, and studies of organisations and human factors. Sources were selected purposively and read within their original settings. No participant data, corporate accident records or experiments were used.

Results: Three preparation needs emerge: instructions that workers can understand, practical authority to interrupt affected work, and continuity of information through response and recovery. Two matrices relate illustrative incident situations to preparation needs and to responsible functions. The resulting proposals cover training on the equipment actually in use, emergency notification, transfer of responsibility and access to technical support across shifts.

Conclusion: Electrification calls for organisational preparation alongside investment in vehicles and charging infrastructure. Managers need to settle who can act, who must be contacted and how unresolved hazards remain visible after the initial response. The proposals offer a basis for local assessment; their usability and effectiveness have not yet been tested.

Keywords: ground handling, electric ground support equipment, organisational preparedness, worker training, emergency communication, lithium ion batteries

1. Introduction

Electrifying airport ground support equipment requires decisions about the workforce as well as about vehicles and charging infrastructure. ACRP Report 78 identified electrification among the main options for reducing emissions from ground equipment (National Academies of Sciences, Engineering, and Medicine [NASEM], 2012), and recent modelling at United States airports has quantified the energy, power and infrastructure demands of fleet conversion (He et al., 2026). The management question addressed here is complementary: how ground handling organisations prepare personnel to recognise and report a battery abnormality and to coordinate the response that follows.

Battery fire research and incident investigations identify toxic emissions, suppression difficulties and possible reignition (Larsson et al., 2017; National Transportation Safety Board [NTSB], 2020; Sun et al., 2020). These findings give reasons for preparation, although they provide no incident rate for airport equipment. The International Federation

of Air Line Pilots' Associations (IFALPA, 2025) has called on airports, rescue and firefighting services, aircraft operators and ground service providers to address battery fires in airside vehicles through risk assessment, procedures, training and equipment. The position states what should be done; it does not say how the work should be divided among the organisations that share an aircraft stand.

That division is not trivial. The organisation operating a vehicle may differ from its owner, from its maintenance provider and from the body controlling the charging infrastructure. Interorganisational safety research associates such arrangements with unclear responsibilities and diluted competence (Milch & Laumann, 2016). Ground handling safety research, for its part, has examined safety culture and human factors (Balk & Bossenbroek, 2010; Ek & Akselsson, 2007), but within the sources reviewed here it has not addressed how a new energy technology redistributes emergency responsibilities on the apron.

The article therefore asks how published battery safety knowledge can inform workforce preparation and coordination in airport ground handling. It makes two contributions. Conceptually, it defines preparedness as the capacity to connect equipment information, worker tasks and accountable decisions throughout response and recovery. Practically, it offers two matrices that managers can use when introducing electric equipment into service. The scope covers lithium ion traction batteries in ground support equipment; aircraft propulsion batteries, batteries carried as cargo and lithium metal batteries are excluded, as are firefighting tactics and comparisons of commercial extinguishing products. Section 2 reviews the relevant literature and closes with the analytical framework. Section 3 describes the review method. Section 4 presents the synthesis, Section 5 discusses its theoretical and managerial implications, its adaptation to different regulatory settings and its limitations, and Section 6 concludes.

2. Literature Review

2.1 Battery hazards and the limits of general instructions

Feng et al. (2018) describe mechanical, electrical and thermal abuse as pathways to thermal runaway, a process driven by interacting reactions inside the cell. The Occupational Safety and Health Administration (OSHA, 2025) lists rising battery temperature, gas or smoke release and fire among the warning indicators. The literature thus separates what can be observed from outside the equipment, such as heat, smell, smoke or a warning signal, from the internal processes that produce those signs.

Larsson et al. (2017) measured hydrogen fluoride emissions in controlled battery fire experiments. Held et al. (2022) analysed soot deposits and cooling water after thermal runaway tests on vehicle battery modules in ventilated and unventilated rooms. Both studies point to smoke exposure and to contamination that outlasts the fire, a concern that is sharper in workshops and charging rooms than on an open apron. Neither was designed to provide evacuation distances for airport equipment.

Ghiji et al. (2020) review battery fire suppression and show that the performance of an agent depends on battery configuration and the conditions of intervention. The NTSB (2020) identifies stranded electrical energy and reignition as hazards both during emergency response and during later vehicle recovery, and SAE International (2019) accordingly addresses first responders and the second responders who tow and store damaged vehicles. Although this evidence concerns road transport, it consistently separates initial fire response from later handling and recovery decisions.

ANSI/CAN/UL 5840 addresses the electrical systems of battery powered aviation ground support equipment, including fire, electric shock and explosion hazards (UL Standards & Engagement, 2025). A design standard governs how equipment is built. It does not allocate duties among the people who operate, maintain or respond to that equipment once it is in service.

2.2 Ground handling as a multiemployer work setting

Ek and Akselsson (2007) found the safety culture of a ground handling company to be generally positive but weaker than its managers estimated. Balk and Bossenbroek (2010) likewise reported that managers and ramp personnel differed in their views of how errors are handled and what causes them. Both studies indicate that managerial judgements of readiness can diverge from the experience of the people who work on the ramp.

Milch and Laumann (2016) identify economic pressure, disorganisation, dilution of competence and differences between organisations as recurring themes in research on interorganisational accidents. OSHA (n.d.-a) recommends that employers sharing a workplace exchange hazard information and agree in advance how safety responsibilities will be carried out. On an aircraft stand, the relevant parties include equipment operators, owners, maintenance providers and the airport functions that control charging points and emergency response.

2.3 Reporting and coordination

Morrison (2014) reviews why employees speak up or remain silent when they hold relevant information. Judgements about whether voice will be effective and whether it carries personal risk are central to that choice. Reporting an uncertain warning and interrupting a task under turnaround pressure is a form of voice in this sense.

Okhuysen and Bechky (2009) identify accountability, predictability and common understanding as the conditions that allow interdependent work to be coordinated. They also describe the mechanisms through which those conditions are produced, including plans and rules, roles, routines, and shared objects and representations. Their framework is used in this review to examine whether each organisation knows its own responsibility, can anticipate the actions of others and holds the information it needs.

Patterson et al. (2004) studied handoffs in space shuttle mission control, nuclear power generation, railway dispatch and ambulance services. They identified strategies such as face to face updates, explicit statement of what has changed and readback of critical information. Their work treats information transfer between people as an organisational task rather than an individual courtesy.

2.4 Production pressure, high reliability and shared awareness

Ramp work is carried out inside a commercial time window. Reason (1997/2016) describes organisations as operating in a space bounded by production and protection, in which the returns on production are immediate and measurable while the returns on protection stay largely invisible, because they consist of accidents that did not happen. Rasmussen (1997) argues that pressure for efficiency, combined with the tendency of workers to economise on effort, moves activity gradually towards the boundary of acceptable performance. Dekker (2011/2016) adds that organisations can drift into failure through a sequence of decisions that each look reasonable in their local context. Applied to a battery warning on the apron, this body of work explains why a worker may continue loading when departure is close: stopping imposes a certain and visible cost on the turnaround, whereas the hazard is uncertain and its consequences lie in the future.

High reliability research examines the same tension from the side of organisations that remain safe under high tempo. Weick and Roberts (1993) studied flight operations on aircraft carriers

and described collective mind as heedful interrelating, in which each member acts with an understanding of how the contributions of others fit together. Weick and Sutcliffe (2015) set out five principles through which such organisations detect and contain weak signals: preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience and deference to expertise. Under the last principle, decisions move to whoever holds the relevant knowledge at that moment, regardless of rank.

Situation awareness research specifies what that knowledge involves. Endsley (1995) defines situation awareness at three levels: perception of the elements in the environment, comprehension of their meaning and projection of their status into the near future. Salas et al. (1995) argue that in teams, awareness also depends on communication and on the coordination through which individual perceptions are combined. On a shared stand, the person who sees smoke from a belt loader is seldom the person who controls fuelling or passenger boarding, so the projection that matters for the aircraft depends on how quickly the observation reaches those functions.

2.5 Training and comprehension

Burke et al. (2006) found that more engaging safety training methods produced greater knowledge acquisition and larger reductions in negative outcomes. Robson et al. (2012) later reported strong evidence that training changes worker behaviour but insufficient evidence for its effect on health outcomes. Together these reviews favour participatory methods while cautioning against claims that training alone reduces injuries.

O'Connor et al. (2014) examine safety education for underserved worker populations and emphasise language, literacy and the fit of training materials to the audience. OSHA (n.d.-b) similarly recommends instruction that workers can understand and that addresses their assigned roles. Salas et al. (2012) place effective training within the organisational conditions that exist before and after a course, including supervisory support and opportunities to practise. Training, in this literature, is a property of the work system as much as of the classroom.

2.6 Regulatory context

The Safety Management Manual of the International Civil Aviation Organization treats the management of change as part of safety management (ICAO, 2018). The European Union Aviation Safety Agency (EASA, 2025) provides guidance supporting ground handling requirements on management systems, personnel training and equipment maintenance. Commission Delegated Regulation (EU) 2025/20 generally applies from 27 March 2028, with its information security provision applying from 27 March 2031 (European Commission, 2025). In the United Kingdom, CAP 642 addresses turnaround coordination, training and airside safety management (Civil Aviation Authority [CAA], 2018). These instruments apply within their own jurisdictions and are cited as institutional context rather than as universal requirements. Section 5.3 considers settings in which comparable provisions are absent.

2.7 Synthesis and analytical framework

Read together, the literature offers four strands that seldom meet. Battery research describes hazards and the limits of what can be observed from outside the equipment. Ground handling and interorganisational research shows that responsibilities on a shared stand are divided and that managerial views of readiness may differ from those of ramp staff. Research on coordination, voice and training explains the conditions under which information is reported, transferred and acted upon. Research on production pressure, high reliability and situation awareness explains why those conditions weaken during a turnaround and how they can be sustained. None of the sources reviewed connects these strands for electric ground support equipment.

This review therefore treats preparedness as the capacity to connect equipment information, worker tasks and accountable decisions throughout response and recovery. Okhuysen and Bechky's (2009) three conditions provide the organising lens: accountability asks who decides, predictability asks whether others can anticipate that decision, and common understanding asks whether the people involved share the information needed to act. Deference to expertise and the distinction between perceiving, comprehending and projecting a hazard (Endsley, 1995; Weick & Sutcliffe, 2015) complement this lens and inform the reading of the matrices in Section 5.1.

3. Methods

The study is a focused narrative review with purposive source selection. Snyder (2019) distinguishes systematic, semi systematic and integrative reviews; the present design follows the integrative logic, whose purpose is to combine diverse evidence into a new framework rather than to estimate effects. Retrieval combined keyword searches, searches for known titles and identifiers, and consultation of publisher and authority websites. Search topics included electric ground support equipment, lithium ion battery hazards, emergency response, ground handling safety, organisational coordination, handover, employee voice, production pressure, high reliability organising, situation awareness and safety training. Sources were retained when they directly informed a hazard, a preparation responsibility or a training decision. No limit on publication year was imposed, and source checks were completed on 10 October 2026 and repeated for the revised version on 5 November 2026.

The review contains 39 sources: 23 scholarly articles or books and 16 institutional, legal or standards documents. Table 1 shows their roles in the synthesis. Bibliographic details were checked against publisher, DOI registry or official issuing body records. Where full texts were unavailable, interpretation was confined to accessible abstracts, summaries or published scope statements.

Table 1. Source groups and their use in the review

Source group (n)	Role in the synthesis	Limit of use
Battery and electrification research (6)	Physical hazards and infrastructure requirements	Cell and road vehicle findings require assessment before airport application.
Incident and standards documents (4)	Response, recovery and equipment design context	Scope statements and guidance do not validate worker procedures.
Aviation and occupational guidance (12)	Institutional responsibilities and operational context	Requirements and recommendations retain their stated jurisdiction and scope.
Organisational, human factors and training studies (16)	Coordination, reporting, work under pressure, comprehension and learning	Findings from other settings inform proposals, not airport effect estimates.
Review methodology (1)	Rationale for narrative synthesis	Purposive selection does not establish exhaustive coverage.

Note. Groups describe each source's primary role in the review; they do not rank evidence quality.

The synthesis proceeded in three steps. First, each source was recorded with its original setting, the claim it supported and the limits of transfer to airport operations. Second, hazard claims were grouped into situations that a ramp worker could observe, which produced the rows of Table 2. Third, each preparation need was assigned to the function holding the relevant information or authority, with accountability, predictability and common understanding used as checks; this produced Table 3.

The review did not use exhaustive database screening, formal quality scoring or independent duplicate extraction, and it estimates no pooled effects or causal relationships. Tables 2 and 3 and the proposals in Section 4 are the author's synthesis. They are not observations of incidents or validated procedures, and this qualification applies to all proposals that follow.

4. Results

The synthesis connects understandable instructions, authority to interrupt affected work and continuity of information. Table 2 identifies decisions that require advance preparation, and Table 3 assigns preparation responsibilities to organisational functions.

4.1 Warning recognition and decision boundaries

Initial instructions should connect observable conditions with achievable decisions. Table 2 distinguishes warnings, apparent active events and recovery needs. These are planning situations, not diagnostic stages through which every incident must pass, and a worker should not wait for one before reporting another.

The practical test is whether each instruction names both an action and the person who owns the decision. "Remove the equipment" leaves open who judges whether movement is appropriate. An operator stop, a charger control and technical electrical isolation are three different actions, not one. Where safe access or authority is uncertain, the plan should not require a worker to approach the equipment simply to complete a checklist.

Table 2. Incident situations and proposed preparation needs

Situation	Preparation needed	Decision boundary
Abnormal heat, smell or battery warning	Define prompt reporting and access to operator instructions for the specific model.	An operator stop is not proof of electrical isolation.
Venting or smoke	Make warning, withdrawal and the airport emergency reporting route familiar.	Do not assign close inspection to establish the cause.
Fire near an aircraft or other services	Agree how affected services receive the warning and how specialist responders gain access.	Aircraft and fuelling decisions remain with their authorised functions.
Impact to the battery area	Provide a route for technical assessment and for restricting further use.	Absence of visible flame does not establish fitness for service.
After apparent fire control	Assign the handover for recovery, monitoring, cleaning and release.	Movement and return to service require separate decisions.

Note. Author synthesis informed by Feng et al. (2018), Ghiji et al. (2020), Held et al. (2022), Larsson et al. (2017), NTSB (2020) and OSHA (2025).

4.2 Allocation of response responsibilities

The proposed initial role for ordinary ramp personnel centres on warning, withdrawal and notification. Specialist firefighting and electrical assessment require separate competence and authority. Decisions about any intervention by ramp staff belong in the local risk assessment and emergency plan, taking account of equipment information and available protection (IFALPA, 2025; OSHA, 2025).

Table 3 allocates preparation responsibilities across the organisations involved, drawing on coordination research and guidance for shared workplaces (Okhuysen & Bechky, 2009; OSHA, n.d.-a). Local agreements must name the authorised personnel and preserve the airport's emergency command arrangements.

Table 3. Proposed responsibilities for organisational preparation

Function	Proposed preparation responsibility	Practical evidence of preparation
Operator or ramp worker	Recognise relevant warnings; know reporting and withdrawal arrangements.	Can explain the local message and identify the emergency contact.
Turnaround coordinator or supervisor	Connect warnings with affected services on the aircraft side; back decisions to stop work.	Named contacts and a workable fallback on every shift.
Equipment owner and maintenance	Provide model information, technical assessment and recovery support.	Accessible instructions and an identified technical contact at all hours.
Airport operator and emergency service	Agree access, emergency activation and interfaces with incident command.	A shared response arrangement and a reviewed exercise record.
Ground handling management	Resource training, maintain responsibility agreements and review changes.	Documented assignment of unresolved actions and review dates.

Note. Author synthesis informed by EASA (2025), CAA (2018), Okhuysen and Bechky (2009) and OSHA (n.d.-a, n.d.-b).

Before equipment enters service, each function should be able to name its counterpart: who supplies technical information outside maintenance hours, who controls a shared charging point and who accepts responsibility for a damaged unit. These questions turn accountability and predictability into checks that can be run during a local exercise.

4.3 Training for assigned duties

Training should follow the equipment and duties assigned to each role. Operators need to recognise relevant warnings and know their operating limits; turnaround coordinators need to pass information to affected services. Neither role carries authority to inspect high voltage components, and neither formal education nor English proficiency demonstrates competence for an emergency duty.

Following O'Connor et al. (2014) and OSHA (n.d.-b), instructions should use the working language of the workforce and familiar descriptions of observable signs, with images of the equipment actually in use. Each message should state the required action and its limit; "be careful" does not help a worker decide whether to continue loading, withdraw or call for assistance.

Brief demonstrations and discussion of realistic situations match the participatory methods examined by Burke et al. (2006). Personnel can practise describing a location,

naming the emergency contact and explaining the difference between an operator stop and electrical isolation, without exposure to an actual battery event. In line with Salas et al. (2012), supervisors should reinforce these points on shift so that the course is not the last occasion on which they are heard.

4.4 Emergency communication and handover

A report should identify the location, the equipment and the observed condition without requiring a technical diagnosis. "Smoke from the electric belt loader at stand 12" gives an emergency recipient something to act on. Because people weigh the usefulness and the personal risk of speaking up (Morrison, 2014), supervisors should make clear that an uncertain condition reported in good faith is welcome, and should explain the decision that follows.

The plan should distinguish emergency activation from management notification and provide a route that remains open when the immediate supervisor is absent. A practice call can confirm whether location and equipment details actually reach the intended recipient.

A handover should carry forward the observed condition, the actions already taken and the restrictions on the equipment, with a named recipient accepting the next responsibility. Drawing on Patterson et al. (2004), it can be made face to face with a readback of the restrictions. Shift changes should preserve the restricted status of the equipment until an authorised decision changes it.

4.5 Recovery and organisational learning

Because of reignition and stranded energy, apparent fire control does not establish readiness for normal handling (NTSB, 2020). Recovery planning should identify who decides on movement, monitoring, cleaning and release, on the basis of technical advice for the model concerned. SAE International (2019) addresses the separate role of second responders, and Held et al. (2022) support a cleaning plan where an event occurs indoors. The review prescribes no universal holding period, separation distance or towing method. Exercises and routine observations can reveal preparation gaps such as an unreachable contact or missing equipment information. Managers should record the responsible function, the corrective action and the review date within existing safety management arrangements, treating the introduction of each new equipment type as a managed change (ICAO, 2018).

5. Discussion

5.1 Theoretical implications

The review recasts preparedness for battery events as a coordination problem with a technical trigger. Battery research specifies the hazard, but the organisational literature explains why a technically correct procedure may still fail in use: responsibilities can be unclear between providers (Milch & Laumann, 2016), workers may hesitate to raise an uncertain concern (Morrison, 2014), and instruction may be poorly matched to its audience (O'Connor et al., 2014). The matrices can be read as coordinating mechanisms in Okhuysen and Bechky's (2009) sense, since they define roles, fix decision rules and provide a shared representation of responsibilities across organisations.

Production pressure research gives a further reason for the weight placed on authority to stop work. Rasmussen (1997) and Dekker (2011/2016) suggest that the imbalance between production and protection described by Reason (1997/2016) seldom produces one

dramatic violation. More often it produces small adjustments, such as finishing the load before reporting a smell, that become normal practice over successive turnarounds. The hesitation to speak up described by Morrison (2014) therefore reflects how the turnaround is measured as much as the judgement of the individual worker. Authority to stop work becomes credible only when supervisors and service agreements accept a delay caused by a good faith battery report as a legitimate outcome.

The matrices can also be read through high reliability and situation awareness research. Table 2 applies deference to expertise (Weick & Sutcliffe, 2015) in two directions. The ramp worker is treated as the person best placed to notice an abnormal sign, and the decision boundaries pass judgements on isolation, movement and return to service to those with the relevant technical competence. The same table separates the levels of situation awareness defined by Endsley (1995). Ramp personnel are asked to perceive and report, while comprehension of the battery state and projection of its development are assigned to functions that hold model information. Table 3 then supplies the communication links through which individual observations become a shared picture across organisations (Salas et al., 1995), and the handover arrangements in Section 4.4 carry that picture across shifts. Together they describe the heedful interrelating that Weick and Roberts (1993) observed on carrier flight decks, adapted to a stand where the participants work for different employers.

The review also extends ground handling safety research. Earlier studies documented gaps between managerial and operational views of safety culture (Balk & Bossenbroek, 2010; Ek & Akselsson, 2007). Technological transition offers a concrete setting in which such gaps matter, because the arrival of electric equipment changes who holds critical information without automatically changing who is expected to act on it.

5.2 Managerial implications

Readiness decisions should accompany procurement and commissioning. Managers can require current emergency information for each equipment model, secure access to technical advice across shifts and agree the handover of damaged equipment before delivery. These arrangements complement the energy and infrastructure planning examined by He et al. (2026) and prevent the arrival of vehicles and chargers from becoming the only test of operational readiness.

Where responsibilities cross organisational boundaries, service agreements should name emergency contacts, information obligations and recovery support. OSHA (n.d.-a) supports agreeing safety responsibilities between employers, including through contract documents, and CAP 642 places turnaround coordination within airside safety management (CAA, 2018). Such agreements must remain consistent with the airport emergency plan and the authority of specialist responders.

Management assurance should then examine whether preparation remains usable after equipment, personnel or suppliers change. Useful checks include access to current instructions, confirmation of handover contacts and closure of exercise findings. Training attendance records and incident counts provide context but cannot on their own show that the organisation is ready.

Punctuality measurement should be examined in the same way. If delays caused by good faith battery reports are recorded under a separate cause and excluded from the performance targets of the crew concerned, the measurement system no longer penalises the behaviour that the emergency plan asks for.

5.3 Adaptation across regulatory settings

Most of the guidance cited in this review comes from European, British and United States sources, where duties between employers who share a workplace are set out in regulation or official guidance. In other jurisdictions, ground handling rules may concentrate on licensing and service quality and say little about emergency duties between providers. The matrices remain usable in such settings if they are attached to instruments that already bind the parties on the apron. Three such anchors can be identified.

The first anchor is occupational safety law. ILO Convention No. 155 requires undertakings that carry out activities simultaneously at one workplace to collaborate in applying its provisions (International Labour Organization, 1981). Ratifying states are expected to give effect to the convention through national laws or regulations, and those laws can support the information exchange set out in Table 3 even when aviation rules are silent. In Türkiye, for example, Article 23 of Law No. 6331 requires employers sharing a work area to cooperate on occupational health and safety measures and to inform one another of risks (İş Sağlığı ve Güvenliği Kanunu, 2012). A ground handler can rely on such a provision when it asks an equipment owner or charging point operator for model information and an emergency contact.

The second anchor is the airport emergency plan. ICAO guidance treats this plan as the instrument through which the airport coordinates the agencies that respond to an emergency (ICAO, 1991), and the ICAO safety management framework lists coordination of emergency response planning among its elements (ICAO, 2018). The plan is often the only document that every party on the apron already recognises. Where multiemployer duties are weakly formalised, it is more practical to have the battery scenarios in Table 2 written into that plan and its exercise programme than to negotiate a separate agreement that some parties may never sign.

The third anchor is the commercial contract. Ground handling and equipment lease agreements can name the technical contact, the information obligations and the recovery support that regulation leaves open, in line with the OSHA (n.d.-a) recommendation to record safety responsibilities in contract documents. Where none of these anchors is available, the matrices can still serve as an internal standard for the handler's own staff. The gaps they reveal, such as a shared charger without a named counterpart, should then be recorded as hazards in its safety management system so that they remain visible to management.

5.4 Limitations

The review is limited by purposive selection and by variable access to full texts. Much of the hazard evidence concerns cells or road vehicles, and the organisational research comes largely from other industries, so transfer to airport equipment depends on the model, the operating environment and local responsibilities. The proposals have not been tested for usability, cost or effectiveness, and they support no prevalence estimates, risk scores or comparisons between occupational groups. The adaptation proposals in Section 5.3 rest on a small number of legal instruments and would need review by practitioners in each jurisdiction.

Evaluation of the proposals should begin with process measures, such as misunderstandings, failed contacts and unresolved handovers observed during exercises, before any attempt is made to measure changes in incident outcomes. The directions this opens for further research are set out in the Conclusion.

6. Conclusion

Preparing for lithium ion battery incidents requires ground handling organisations to connect equipment knowledge with workable responsibilities. The review shows that the main preparation needs are understandable instructions, usable authority to interrupt affected work and continuity of information through response and recovery. Its significance lies in treating electrification as an organisational change as well as a technical one, and in giving managers two matrices for agreeing initial worker actions, emergency communication and ownership of recovery before equipment enters service. Future research should test these proposals in tabletop and live exercises across ground handlers, equipment owners, airports and rescue and firefighting services, examine whether ramp personnel understand locally adapted instructions, and explore how willing they are to stop work when a battery warning appears close to departure. Until such evidence is available, the proposals should be adopted only after local testing.

Declarations

Research ethics and data availability. This narrative review involved no human participants, identifiable personal data or animal research. No new empirical dataset was generated. The sources supporting the synthesis are listed in the references.

Funding. No specific external funding was received for the preparation of this review.

Competing interests. The author declares no competing interests relating to this manuscript.

Use of artificial intelligence. OpenAI ChatGPT and Anthropic Claude were used for language editing and document preparation. They were not used to generate participant responses, incident observations or experimental results. Responsibility for verification and the submitted content rests with the author.

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