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# Guidance Document on Building Resilient E-bus Ecosystem

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# Preface from GIZ India

The Ministry of Housing and Urban Affairs (MoHUA) is implementing a technical cooperation project **Sustainable Urban Mobility- Air Quality, Climate Action and Accessibility (SUM-ACA)** with support from Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) India, as part of the Green Urban Mobility Partnership (GUMP) between Germany and India. Commissioned by German Federal Ministry for Economic Cooperation and Development (BMZ), the project aims to strengthen national, state, and municipal institutions in advancing climate-friendly, low-emission, and socially inclusive urban mobility systems. Targeted interventions are being implemented at the national level and in volunteer cities across five partner states viz., Kerala, Karnataka, Odisha, Meghalaya, and Gujarat, under the SUM-ACA project.

As India transitions to electric buses, the need for disaster-resilient e-bus infrastructure has become critical. E-bus depots and their supporting grid networks may face multifaceted risks from fire hazards linked to lithium-ion batteries to flood, cyclone, and grid disruption vulnerabilities. To address these emerging challenges SUM-ACA project supported MoHUA in developing a **Guidance Document on Building Resilient E-Bus Ecosystem**. The initiative emphasizes upon disaster preparedness, risk minimisation and resilient design principles for e-bus depots and associated infrastructure. It aims to strengthen institutional capacities, establish standard operating protocols, and build technical readiness for prevention and management of hazards effectively ensuring that India's e-bus systems remain safe, reliable, and sustainable even under adverse climatic conditions.

Through such forward-looking initiatives, GIZ India continues to serve as a knowledge and implementation partner, facilitating India's vision for green, inclusive, and disaster-resilient urban mobility.

# About the Report

India's transition towards environmentally sustainable urban mobility has gained momentum through large-scale deployment of electric buses (e-buses) under National Schemes and Programmes such as FAME, PM e-Bus Sewa, PM E-DRIVE, etc., along with various State EV policies. This shift promises improved air quality, reduced carbon emissions, and enhanced public transport services. However, the electrification of public transport introduces new and evolving challenges related to safety, reliability, and disaster resilience.

The Electric Bus Ecosystem (EBES) is a highly interdependent network comprising of rolling stock, depots, charging systems, and the wider urban environment, with each element exposed to  a range of potential hazards/ disruptions leading to disruption. Floods can damage batteries and electrical systems; heatwaves can trigger thermal events; cyberattacks can disrupt operations; and human errors or vandalism can compromise safety. Resilience in the e-bus ecosystem refers to its ability to withstand, adapt to, and rapidly recover from such disruptions while ensuring continuity of mobility services and supporting grid stability. Achieving this resilience requires a coordinated, system-wide approach based on robustness, redundancy, resourcefulness, rapid recovery and active engagement of all stakeholders.

This **Guidance Document on Building Resilient E-Bus Ecosystem** provides a strategic and operational framework to strengthen disaster preparedness and resilience in the ecosystem. It is intended for public bus transport agencies (e.g., STU, MTU, SPV), infrastructure developers, engineers, OEMs, policymakers, and regulators involved in the planning, design, and operations of e-bus ecosystem.

The document begins with a risk landscape and risk assessment framework adapted from the Asian Development Bank's bivariate matrix method, enabling cities to assess hazard likelihood, exposure, and vulnerability. This diagnostic approach helps identify key gaps between E-Bus Ecosystem Resilience requirement and availability such as absence of hazard-specific SOPs, limited monitoring systems, and weak institutional coordination.

Building on these insights, the document presents a comprehensive disaster management plan providing robustness and in-built resourcefulness, effective response mechanism and rapid recovery capability in the EBES, inter-alia covering **prevention, mitigation**, **response** and rapid **recovery** measures across disruptions caused by hazards such as floods, cyclones, heatwaves, earthquakes, grid instability, battery fires, cyber threats and more. For each scenario, it defines possible range of technical designs and standards for building up system robustness, provisioning that including redundancies, quality assurance protocols and capacity building requirements besides institutional and financial arrangements for adequacy of resources in rapid recovery from disruptions at all stages of disruption namely pre-disaster, during disaster and post disaster phases.

Beyond the technical measures, the document identifies critical enabling pillars that form the foundation of resilience within the EBES, anchored in institutional strength, capacity building, financial security, and policy coherence:

1. **Institutional Resilience:** Creation of an institutional set up headed by a Chief Transport Safety Officer (CTSO) within each transport agency to plan, develop, maintain and implement a robust EBES disaster resilience system, and to effectively coordinate inter agency functions for safety and quick response.
2. **Capacity Building:** Organising structured training programs for bus crew, depot staff, engineers, DISCOMs personnel, and emergency responders, supported by agencies like NIDM, ULBs, and Fire Departments.
3. **Financial Preparedness:** Development of EBES-specific risk insurance products, contingency funds, and linkages with climate adaptation financing].
4. **Policy and Regulatory Reform:** Undertaking revisions to Fire Safety Acts, Motor Vehicles Act, amongst others and inclusion of resilience clauses in procurement and safety certification frameworks, EBES policies.

In essence, the document serves as a strategic blueprint for embedding resilience into India’s e-bus ecosystem and may also be used as a reference for Gross Cost Contract (GCC) procurement by CESL. By integrating technical, institutional, financial, and policy enablers, efforts are made to bring in system robustness, improve its resourcefulness and redundancies for rapid recovery of EBES from disaster to ensure that the nation’s e-bus transition remains not only sustainable but also safe, adaptive, and future-ready. It is anticipated that this guidance will evolve in line with technological advancements and key learnings from operators. Accordingly, efforts should be made to periodically update the document to reflect emerging best practices and sectoral developments.

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# List of Abbreviations

| | |
|---|---|
| **AIS** | Automotive Industry Standards |
| **ADAS** | Advanced Driver Assistance System |
| **BMS** | Battery Management System |
| **BRTS** | Bus Rapid Transit System |
| **CCTV** | Closed-Circuit Television |
| **CESL** | Convergence Energy Services Limited |
| **CMVA** | Central Motor Vehicles Act |
| **CMVR** | Central Motor Vehicles Rules |
| **CSC** | City-level Safety Committee |
| **CTSO** | Chief Transport Safety Officer |
| **DISCOM** | Distribution Company |
| **DMA** | Disaster Management Authority |
| **DDRF** | District Disaster Response Force |
| **DDMO** | District Disaster Management Officer |
| **DDMA** | District Disaster Management Authority |
| **DFMS** | Driver Fatigue Monitor System |
| **DG** | Diesel Generator |
| **ECUs** | Electronic Control Units |
| **ERO** | Emergency Response Officer |
| **ERTs** | Emergency Response Teams |
| **E-Bus** | Electric Bus |
| **EBES** | E-Bus Ecosystem |
| **ESS** | Energy Storage System |
| **EV** | Electric Vehicle |
| **EVSE** | Electric Vehicle Supply Equipment |
| **EWS** | Early Warning System |
| **FDAS** | Fire Detection and Alarm System |
| **FAME** | Faster Adoption and Manufacturing of Electric Vehicles |
| **FR** | Flame Resistant |
| **FMVSS** | Federal Motor Vehicle Safety Standards |
| **FPS** | Fire Protection System |
| **GCC** | Gross Cost Contract |
| **GIS** | Geographic Information System |

| | |
|---|---|
| **HMI** | Human Machine Interface |
| **HVAC** | Heating, Ventilation, and Air Conditioning |
| **HT/EHT** | High Tension/ Extra High Tension |
| **ICE** | Internal Combustion Engine |
| **IEC** | International Electrotechnical Commission |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **IMD** | India Meteorological Department |
| **IP** | Ingress Protection |
| **IRTE** | Institute of Road Traffic Education |
| **IS** | Indian Standards |
| **ITS** | Intelligent Transport System |
| **ITMS** | Integrated Transport Management System |
| **LFP** | Lithium Iron Phosphate |
| **LT** | Low Tension (Electrical) |
| **MCCB** | Moulded Case Circuit Breaker |
| **MoHUA** | Ministry of Housing and Urban Affairs |
| **MoRTH** | Ministry of Road Transport and Highways |
| **NBC** | National Building Code |
| **NDMA** | National Disaster Management Authority |
| **NEBP** | National Electric Bus Program |
| **NFPA** | National Fire Protection Association |
| **NIDM** | National Institute of Disaster Management |
| **NISA** | National Industrial Security Academy |
| **NOC** | No Objection Certificate |
| **OEM** | Original Equipment Manufacturer |
| **OCPP** | Open Charge Point Protocol |
| **OCPD** | Overcurrent Protection Device |
| **PBTA** | Public Bus Transport Agencies |
| **PIS** | Passenger Information System |
| **PPE** | Personal Protective Equipment |
| **PQM** | Power Quality Meter |
| **RCA** | Root Cause Analysis |
| **RCD** | Residual Current Device |
| **RMU** | Ring Main Unit |
| **SCADA** | Supervisory Control and Data Acquisition |

| | |
|---|---|
| **SDMA** | State Disaster Management Authority |
| **SOH** | State of Health |
| **SOP** | Standard Operating Procedure |
| **SPV** | Special Purpose Vehicle |
| **STA** | State Transport Authority |
| **STU** | State Transport Undertaking |
| **TLS** | Transport Layer Security |
| **ToT** | Training of Trainers |
| **UTSC** | Urban Transport Safety Cell |
| **UBS** | Urban Bus Specifications |
| **ULBs** | Urban Local Bodies |
| **UNECE** | United Nations Economic Commission for Europe |
| **UPS** | Uninterruptible Power Supply |
| **VCU** | Vehicle Control Unit |
| **VGF** | Viability Gap Funding |
| **VMS** | Variable Message Sign |
| **VOC** | Volatile Organic Compounds |
| **WRI** | World Resources Institute |

# EXECUTIVE SUMMARY

## Why does India need a Guidance Document on Building Resilient Electric Bus Ecosystems?

India's journey towards sustainable urban mobility has taken a decisive turn with the large-scale deployment of electric buses (e-buses) across its cities. Supported by national programs such as FAME II, PM e-Bus Sewa, PM E-DRIVE, and state-level EV policies, this transition promises improved energy efficiency, reduced oil dependency and lower local air pollutions. However, as more Indian cities adopt e-buses, new safety and operational challenges are emerging.

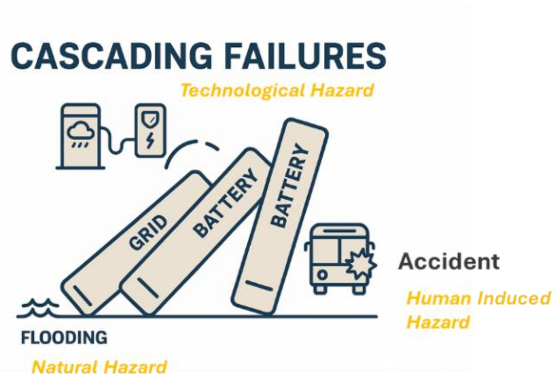



Exhibit 1 Cascading Impact on E-Bus Ecosystem

E-buses operate within a highly interdependent ecosystem comprising fleet, charging infrastructure, depots, and the broader urban environment. This complex ecosystem is observed to be sensitive to varied range of hazards such as extreme temperatures, increasing flash floods and consequent water ingress into the EBES items, accidental collision causing battery overheating and consequent thermal runaway, earthquake, grid instability, cybersecurity breaches and more disruptions expected over time. Each hazard trigger cascading failures affecting passenger safety, damaging batteries and electrical system, disrupting operational reliability, and eroding public confidence. To ensure a safer and sustainable transition to e-buses, there is an urgent need for designing the ecosystem to prevent and withstand disruptions from natural disasters to technological failures and human-induced incidents. In other words, the EBES is planned to be developed as a resilient system by making it robust to withstand disruptions, provide requisite resources including redundancies to effectively handle disruptions and then quickly recover the EBES to normal operations.

## For whom is this guidance document designed?

To ensure comprehensive resilience, the document brings together all the key actors who shape, operate and safeguard the system. It is therefore intended for a wide range of stakeholders including public bus transport agencies[1] and operators responsible for day-to-day operations and emergency readiness. The infrastructure developers and engineers who design and maintain safe and resilient depots and charging infrastructure and the original equipment manufacturers (OEMs) tasked with integrating hazard-resistant features in vehicles and their sub-systems. It also involves policymakers and regulators in framing technical standards, safety protocols, and enabling regulations that collectively strengthen the resilience of the E-Bus Ecosystem (EBES)[2].

[1] Public Bus Transport Agencies that manage public bus services in urban cities such as State Transport Undertaking (e.g. Karnataka State Road Transport Corporation), Municipal Transport Undertaking (e.g. Bengaluru Municipal Transport Corporation) and Special Purpose Vehicle (e.g. Sitilink, Surat).

[2] EBES is defined as an integrated system primarily comprising the e-bus fleet, depots, charging infrastructure, and operating environment that collectively enable safe, reliable, and resilient electric bus operations. While the EBES includes additional elements, this document focuses on these four components due to their significance in relation to potential hazards.

## What does E-Bus Ecosystem Resilience mean?

Resilience in the E-Bus Ecosystem (EBES) refers to the inherent ability of its interconnected components including e-buses, charging infrastructure, depots, and the supporting power grid to withstand, adapt to, and rapidly recover from disruptions. Unlike fossil-fuelled buses, e-buses are closely integrated with the electrical grid, therefore, grid resilience is essential to ensure continuity of transport services, even during power grid emergencies. The following exhibits showcases the four key principles of EBES resilience.

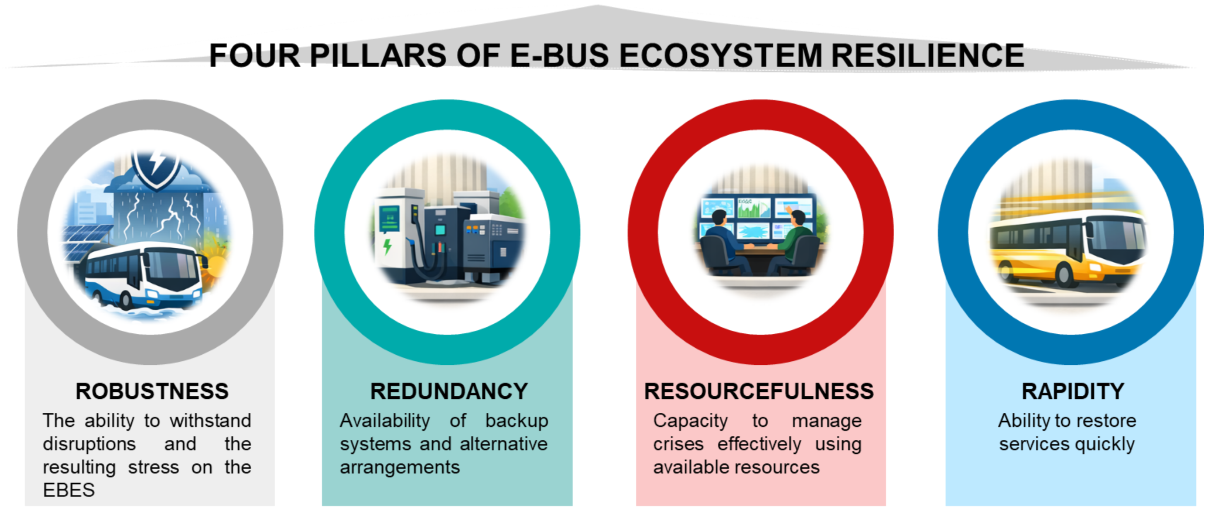



*Exhibit 2 Four pillar of E-bus Ecosystem Resilience*

## What are the core components of the E-Bus Ecosystem for determining resilience?

Further, a resilient EBES is built around four interconnected components namely the fleet, depots, charging infrastructure and the operating environment. Each component performs a distinct function, yet failure in anyone tends to cause a cascading effect across the system, disrupting service delivery and compromising safety. Recognising these interdependencies is central to designing a comprehensive disaster-resilient EBES framework.

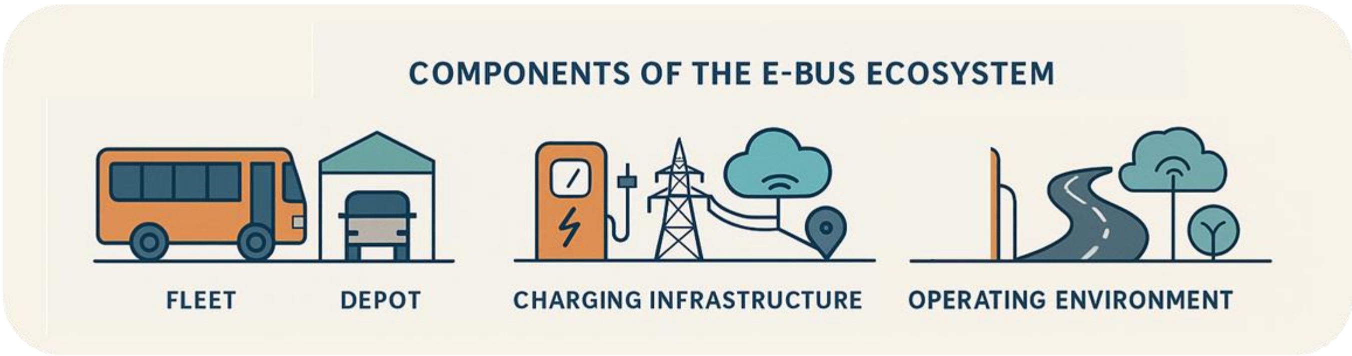



*Exhibit 3 Components of E-Bus Ecosystem*

The **Fleet of e-buses** forms the primary interface between the **transport system** and passengers, making optimal service delivery non – negotiable. The robustness in bus design and placement of battery packs coupled with onboard safety system collectively determine how well e-buses can withstand hazards and ensure resilience.

**Depots** serve as the operational backbone of the EBES, housing vehicles and charging infrastructure, repair and maintenance and other facilities besides the depot staff, thus making it highly vulnerable to potential hazards. Therefore, resilient depot design and efficient layout is necessary to safeguard the assets and personnel and enable rapid restoration of transport services after disruption.

The **Charging Infrastructure** that transfers electrical energy from the grid to the on-board electric energy storage system i.e. the battery packs of e-buses forming the energy lifeline of the fleet. It encompasses chargers, substation, transformer, cabling and energy management systems. Thus, building resilience in this sub-system therefore requires redundancy, robust safety mechanism, a reliable grid connectivity and assured power quality.

The **Operating Environment** encompasses the broader urban system in which e-buses operate, including corridors, stations, enroute passengers, crew and other road users besides the supporting IT systems. Strengthening resilience at this level ensures passenger safety and service reliability, even during extreme events or system disruptions.

While EBES includes several other elements, this guidance document focuses on these four components in view of their critical exposures to hazards.

## *How does the document help cities understand and assess their risks?*

The document is structured in a multi-step process that draws learnings from Indian and International design standards, global case studies and risk and vulnerability mapping, while integrating it with technical analysis, stakeholder input, and practical application as explained in the adjacent exhibit. These risks are classified basis three categories of hazards: Natural, Technological and Human Induced Hazard.

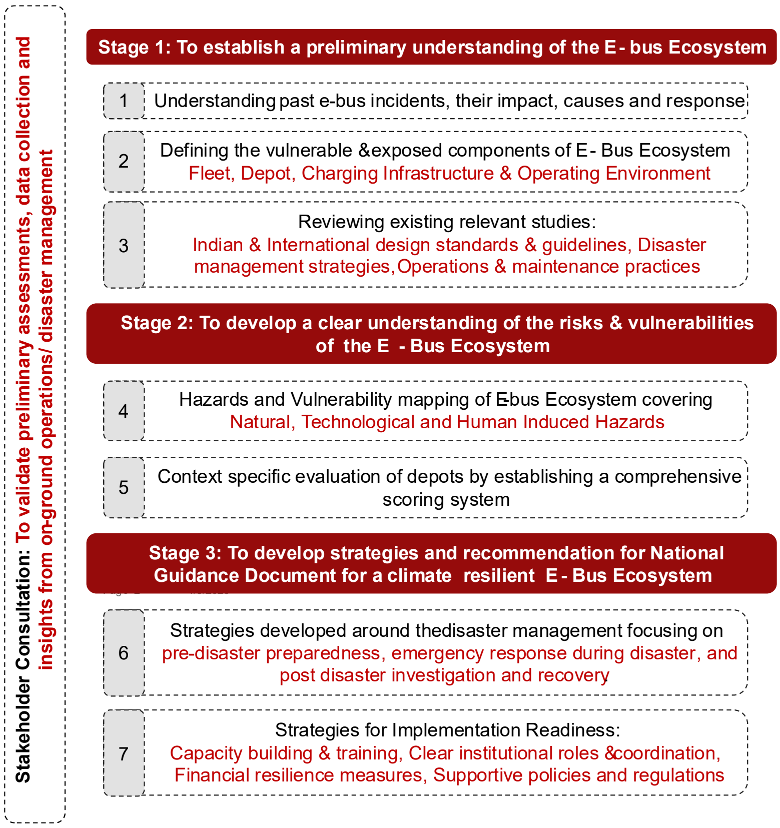



*Exhibit 4 Approach and Methodology for developing the Guidance Document*

Given the wide range of hazards that can affect the EBES, a diagnostic and data driven approach has been developed. Further, a structured risk assessment framework has been adapted from the Asian Development Bank's (ADB) bivariate matrix method, enabling cities to evaluate hazard likelihood and intensity, the exposure of assets, and vulnerability of the EBES. Exposure and vulnerability are combined to derive a consequence score weighted at 70% and 30% respectively in line with ADB practice, with flexibility for cities to adjust weightages based on local risk contexts. The final risk score is worked out by overlaying hazard likelihood onto a 5×5 risk matrix, classifying risks from very low to very high. By providing a structured and adaptable assessment tool, the framework supports evidence-based risk mitigation, strengthens resilience planning, and helps cities safeguard critical e-bus infrastructure and ensure continuity of public transport services.

## What disaster management solutions are outlined in the document?

Building on the gaps identified through literature review and risk assessment, the document presents a comprehensive disaster management plan. It offers detailed strategies for prevention, mitigation, and restoration across various hazard scenarios including floods, cyclones, heatwaves, earthquakes, grid instability, battery fires, cyber threats, and more. For each component, it outlines technical design standards, inspection protocols, maintenance routines, and training requirements. The detailed recommendations for each hazard are given for three stages that are pre-disaster/ pre-planning, during disaster and post disaster stages.

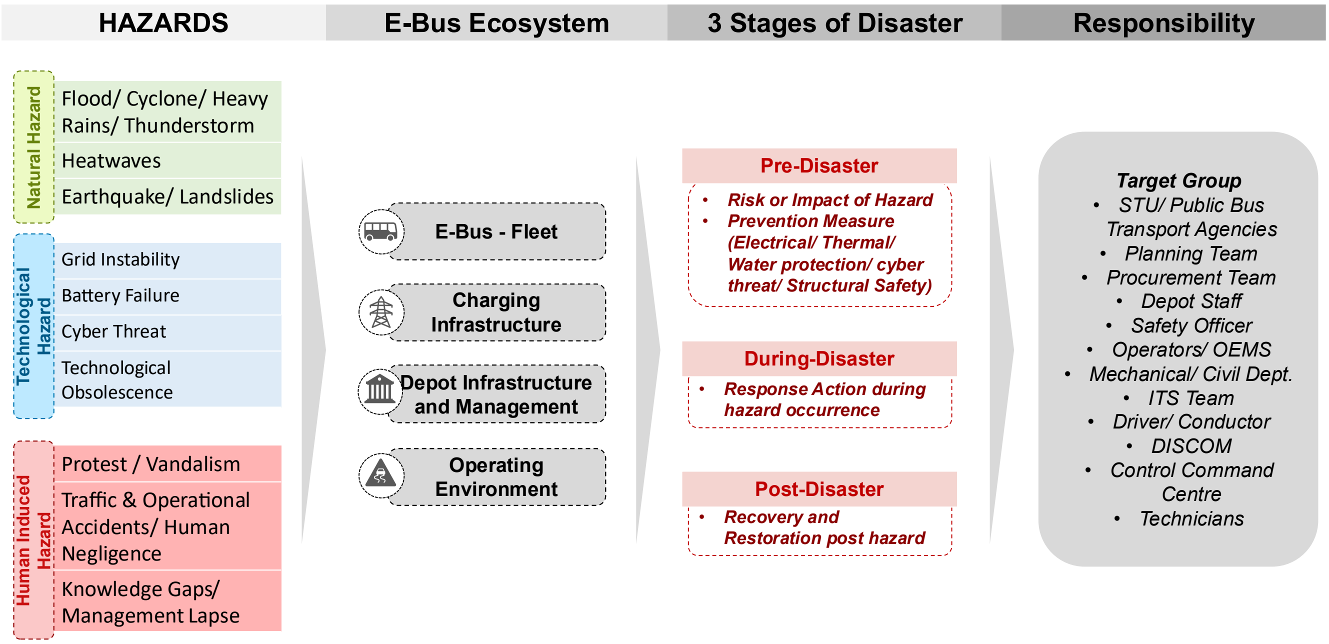



*Exhibit 5 Hazard Impact Framework*

## What proactive design and planning approaches can enhance pre-disaster preparedness and resilience in the E-Bus Ecosystem?

The pre-disaster section outlines a comprehensive design, safety, and operational recommendations for the e-bus fleet, covering its full lifecycle from planning and procurement to operations, monitoring, capacity building and end of life stages. It emphasizes that **fleet resilience** be embedded at as a preventive measure at the planning, design and construction stages through compliance with Indian and global safety standards such as Automotive Industry Standard (AIS), Urban Bus Specification – II (UBS II), Central Motor Vehicle Rules (CMVR), United Nations Economic Commission for Europe (UNECE), Federal Motor Vehicle Safety Standards (FMVSS) and National Fire Protection Association (NFPA). It also highlights the need for robust battery and thermal management systems, along with water and cyber protection, and structurally safe battery integration. In addition, public bus transport agencies are encouraged to adopt city-specific mitigation strategies and safety measures aligned with local risks and hazards to further strengthen fleet resilience.

Key consideration for optimal selection of on-board Energy Storage System (ESS - the battery pack) include battery-chemistry affording high resistance to fire and thermal run-aways, optimal energy storage density and compliance with national and international safety standards, suitability for operations in the applicable environmental conditions. The battery packs be duly certified by the notified agencies and their replacement be planned after 5-6.5 years of usage or when the state of health (SOH) falls below 80%. Safe usage and charging practices be followed to prevent deep discharge and over charge as both conditions likely to cause overheating and consequent thermal runaways. Fire detection and suppression systems are recommended to be installed near battery packs along with alarm and Fire Protection System (FPS) in the passenger area to control any possible breakout of fires, alert occupants and automatically deploy high sprinkling water mist to suppress the fire. The battery packs be effectively cooling maintaining preferred temperature range of the battery packs between 15°C and 35°C for maximising battery performance, lifespan and safety. All applicable electrical design compliances for protection against flooding, corrosion, and for safeguarding the digital onboard systems from cyber threat be ensured. These technical measures are reinforced through disciplined preventive maintenance, rigorous inspection and certification regimes, real-time monitoring via Battery Management System (BMS) and telematics, and the defined hierarchical alert-response mechanisms. Equally critical is the need for capacity building including training of drivers on safe driving practices, battery conditions monitoring, emergency response, and use of safety technologies such as Advanced Driver Assistance System (ADAS) and Driver Fatigue Monitoring System (DFMS), along with training depot staff to effectively manage emergencies arising from floods and other disasters.

Strategic site selection, decision related to converting an Internal Combustion Engine (ICE) depot to an e-bus depot and the design of **E-Bus depot** is critical pre planning steps. Depots be located away from flood hazards, seismic fault lines, landslide risks and coastal areas, while maintaining close proximity to reliable power supply infrastructure and designated e-bus routes.

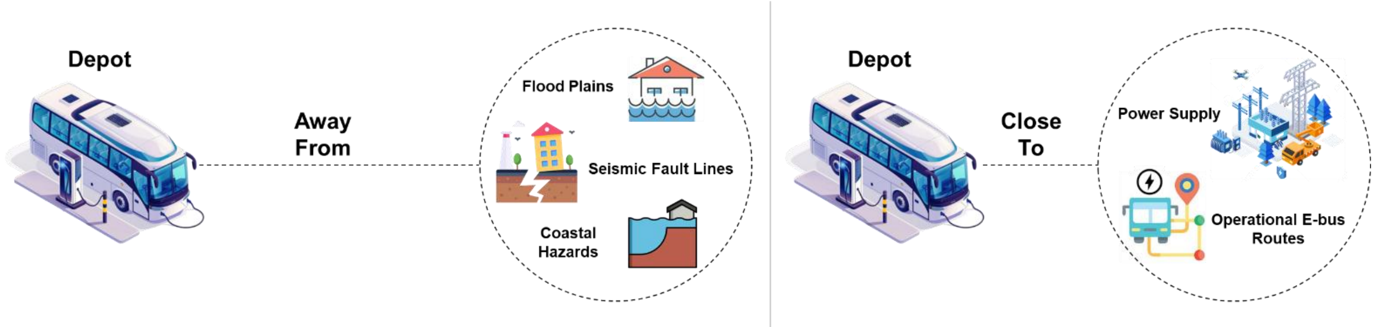



*Exhibit 6 Depot Site Location*

Depot layouts should prioritise compartmentalised parking of e-buses (e.g. lots of 25 e-buses per fire-segregated space with 4–5 meters separation between such spaces), provide dedicated charging, quarantine zones, battery storage, disposal areas and unidirectional vehicle movement to minimise any friction during movements. These measures enable smooth and streamlined circulation during routine day-to-day operations as well as during emergency and disaster events. Electrical and fire safety systems must comply with applicable standards such as IS 3043, IS 732/IEC 60364, IEEE 1584, NBC 2016 Part IV, IS 2189 and other relevant codes, support fire detection and suppression systems, thermal imaging, and emergency power isolation. Flood resilience measures such as raised plinths above highest flood level, robust drainage and pumping systems, auto cut-offs and other safety measures be integrated at the design stage. Depot's structural design should align with earthquake and cyclone-resistant byelaws. Cybersecurity protocols, Supervisory Control and Data Acquisition (SCADA)/ BMS based real-time monitoring and India Meteorological Department (IMD) linked early warning systems be provided to further enhance preparedness. These physical measures be reinforced through strict approval processes, third-party safety audits, certified manpower with appropriate Personal Protective Equipment (PPE), detailed SOPs, regular trainings and mock drills.

**Charging infrastructure** is the energy backbone of the EBES encompassing upstream power systems (substations and transformers), switchgear, and charging stations, and therefore demands the highest standards of safety, reliability, and resilience. Planning and design of charging set up to be based upon accurate load estimation considering the fleet size, battery capacity, charger type, and charging windows, with close coordination with DISCOMs to ensure adequate High Tension/ Extra High Tension (HT/EHT) supply and future scalability. Infrastructure should comply with applicable key Indian and international standards such as AIS-138, IS 17017, IS 15118, IEC 61851, IEC 605, IEC 60076, IEEE 519, and other relevant codes to ensure electrical safety, interoperability, and cyber resilience. Design measures should address protection against major hazards through elevated and minimum IP 65 (Ingress Protection) rated enclosures for flood protection, arc-flash-safe and oil-free switchgear, robust earthing, surge and lightning protection, effective thermal management systems and fire detection and suppression systems.

Operational resilience is strengthened through SCADA/BMS-based real-time monitoring, remote shutdown and fault isolation, CCTV and access control, preventive maintenance, third-party inspections, and clearly defined SOPs for emergencies, lightning events, and extreme weather forecast. Grid resilience measures include dual power feeds, renewable energy system integration, and battery energy storage to further ensure continuity of operations.

A safe and resilient **operating environment** is critical to the reliable functioning of e-buses and delivery of high-quality and safe commuter services. This requires integrated route and operations planning that aligns vehicle range, route characteristics, crew preparedness and real-time risks assessment, proactively identifying hazard-prone corridors and embedding mitigation measures for electrical, thermal, flooding, cyber, and structural risks. Effective coordination with emergency services such as fire stations, ambulances, traffic police, DISCOMs, and the operator control room is essential for rapid incident response. This coordination be supported by clear communication channels and real-time alerts from agencies such as IMD and state/urban disaster management authorities. System-wide preparedness be strengthened through well-defined and consistently implementable Standard Operating Procedures (SOPs) covering emergency response, passenger evacuation, asset isolation, and service suspension or diversion during extreme events. The following illustration outlines a framework for strengthening operational resilience and passenger safety through advanced technologies, robust safety systems, and continuous capacity-building.

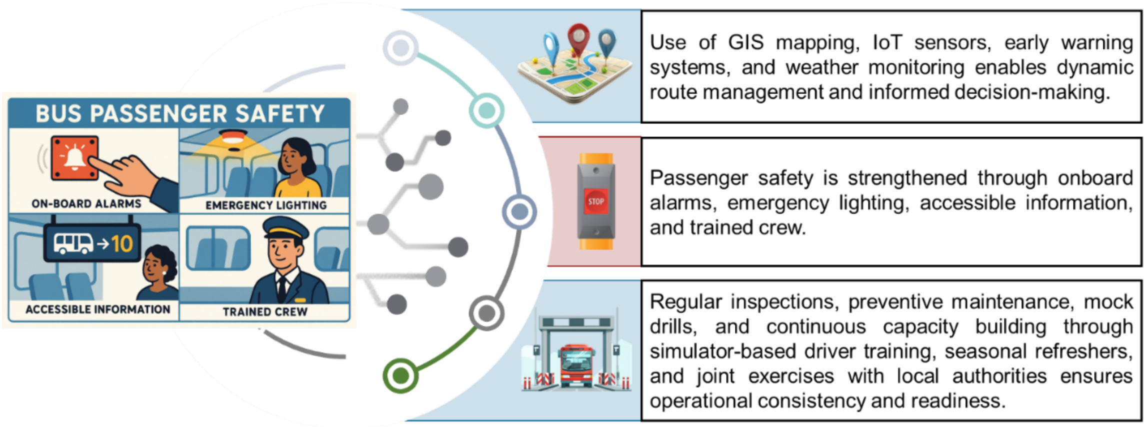



*Exhibit 7 Framework for strengthening Operational Resilience and Passenger Safety*

## How can coordinated emergency response and SOPs ensure safety and service continuity during disasters in the E-Bus Ecosystem?

During natural, technological and human induced hazards such as floods, cyclones, earthquakes, grid instability, battery failures, accidents, protest and vandalism, a clear and coordinated emergency response framework is essential. It helps safeguard lives, protect critical assets, and maintain operational continuity across the four core components of the EBES: fleet, depots, charging infrastructure, and the operating environment.

At the heart of this framework is a robust, multi-layered communication protocol, with the Control Room functioning as the central command hub for hazard monitoring, alert dissemination, and activation of emergency procedures. Clearly defined internal communication channels connect senior manager at headquarters, managers and staff at the depot, fleet controllers on site, and drivers/ bus crew in operations through ITMS, radio/VHF, and secure messaging platforms. Externally, timely communication and coordination with emergency services, alongside transparent passenger communication supported through mobile applications, SMS alerts, and public announcements. The illustration here under presents incident-specific response protocols to enable rapid, structured, and effective action across natural, technological, and human-induced emergencies.

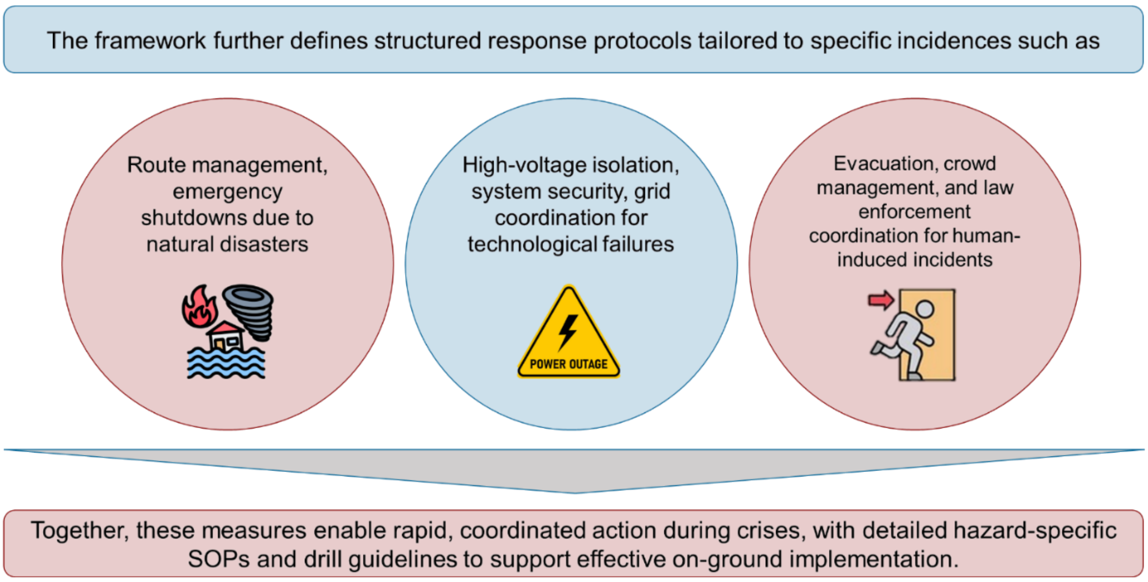



*Exhibit 8 Framework defined for structured response protocols during disasters*

## *How can structured post disaster response and recovery actions restore service and strengthen resilience in the E-Bus Ecosystem?*

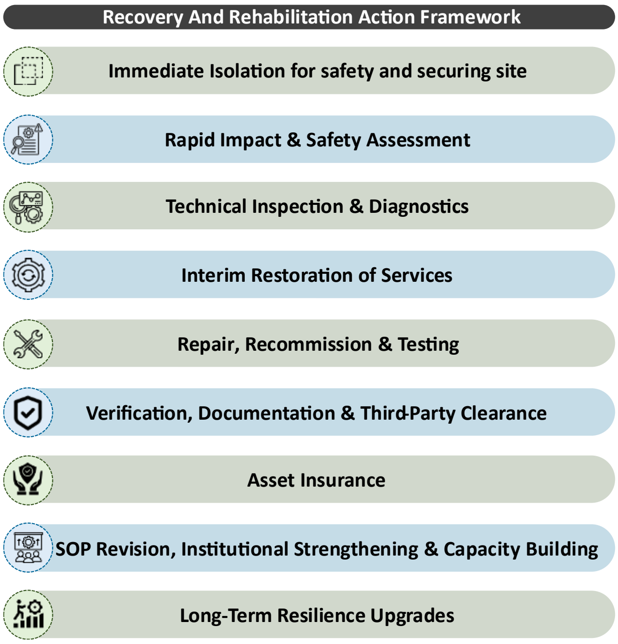



*Exhibit 9 Post Disaster Recovery and Rehabilitation Action Framework*

In the event of natural, technological or human induced hazards, a standardised and system wide response and recovery framework is essential to quickly restore safe operations and ensure service continuity across EBES components as described above. The framework adopts a sequenced approach, beginning with immediate isolation of the hazard impacted asset and site securing to eliminate/ minimise safety risks, followed by rapid impact assessment and detailed technical diagnostics conducted by certified personnel and OEMs. Assets are then systematically classified based on operational safety, enabling informed decisions on phased service restoration using standby fleets, route diversions, temporary charging arrangements, or manual operations to maintain essential mobility particularly for health and other critical urban services. The framework emphasises structured repair, testing, and third-party verification prior to recommissioning, supported by thorough documentation, insurance processing, and regulatory reporting.

Beyond short-term recovery, it institutionalizes learning through SOP revisions, targeted training, and post-incident drills, while guiding long-term resilience upgrades such as flood-proofing, fire-rated infrastructure, and enhanced backup power aligned with national and international resilience standards. Standardised checklists and assessment tools, detailed in the annexures, ensure consistent, data-driven evaluation across components, enabling cities to restore services rapidly while strengthening the resilience and reliability of e-bus operations over time.

## *What Institutional arrangements are needed to anchor resilience?*

Beyond the disaster management plan, policies must set critical enablers to forming the backbone of resilience in the EBES anchored in people and capacity building. The first pillar is a streamlined **institutional architecture**. Instead of multiple new institutional bodies, the framework proposes the appointment of a designated Chief Transport Safety Officer within State Transport Undertaking (STU), Municipal Corporation, Special Purpose Vehicle (SPV), or relevant public bus transport agencies. To this single point must be assigned accountabilities for all aspects related to the disaster resilience of e-buses - fleet, charging systems, depots, and the operating environment. At the operational level, depot-based Emergency Response Teams (ERTs) are established to enable swift, coordinated action during incidents involving high-voltage systems, fires, floods, or cyber disruptions. The structure is further reinforced through formal inter-agency coordination with fire services, disaster management authorities, utilities, and OEMs, alongside national-level mechanisms for policy updates, centralised incident monitoring, and continuous institutional learning. Together, this architecture promotes clear accountability, proactive risk management, and resilient e-bus operations.

## How does the document address capacity building and skills development?

The second pillar is a robust **capacity building framework**. The EBES is inherently complex due to charging and battery management requirements, the sensitivity of high voltage system and the interdependent nature of its infrastructure. Consequently, targeted and continuous training across all stakeholders including crew, depot staff, planners, DISCOM, and emergency responders are essential. The framework maps role-specific training needs across domains such as crew safety, depot risk management, battery handling, charging operations, grid coordination, ITMS monitoring, and fire management. It also emphasizes inter-agency collaboration, leveraging the mandates of disaster authorities, fire departments, Urban Local Bodies (ULBs), National Institute of Disaster Management (NIDM) and development partners to create a unified, nationwide culture of preparedness and resilience.

## Why is financial resilience critical for e-bus ecosystems?

**Financial resilience** forms the third pillar. The document highlights the need for EV-specific insurance products covering battery fires, flooding/ water ingress, and composite risks as well as contingency funds, viability gap funding adjustments, and integration with climate adaptation programs. It calls for proactive financial planning to ensure that cities can recover quickly from disruptions without compromising service delivery.

## What policy and regulatory reforms are recommended?

Finally, the document outlines the fourth pillar which is a series of **policy and regulatory reforms**. These include amendments to State Fire Acts and the Motor Vehicles Act to incorporate EV-specific hazards, integration of e-bus risks into disaster management frameworks, mandatory depot safety certifications, and inclusion of resilience clauses in procurement contracts. It also recommends the development of a national EV hazard map and safety rating system for depots.

## What is the overall value of this guidance document?

In essence, this guidance document is not just a technical manual, it is a strategic blueprint for embedding resilience into India's e-bus transition and should be read and implemented alongside prevailing policies and guidelines issued by the relevant line ministries governing e-buses and the broader electric mobility ecosystem. By addressing the technical, institutional, financial, and policy aspects of disaster preparedness, it empowers cities to deliver safe, reliable, and climate-resilient public transport services. As India scales up its e-bus adoption, this document will serve as a critical guide for ensuring that progress is not only sustainable, but also secure and future-proof.

# Reference Guide for the Document

This Guidance Document on Building Resilient EBES is structured in three modules comprising of twelve chapters. Readers may explore the document sequentially or navigate directly to the sections most relevant to their needs, guided by the suggestions provided below.

**Introduction to the Document**

Understand the context, purpose, objectives, approach and limitations of the guidance document

**Part A: Setting the Charge: Building a Resilient Future for E-Bus Infrastructure**

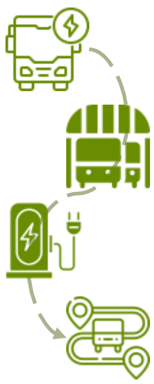
**Chapter 1**

The New Age Mobility – Unlocking Potential with Resilience

Explore the foundation & need for the guidance document

**Chapter 2**

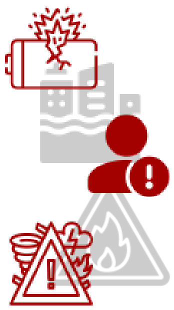
Context Setting for the Guidance Framework for Resilient E-Bus Ecosystem



- Familiarize with key component of the e-bus ecosystem including e-buses, depot infrastructure and management, charging Infrastructure and the operating Environment
- Understand how hazard specific recommendations are structured across the three stage of disaster management and by the intended user group

**Chapter 3**

Navigating the Risk Landscape: Mapping Threats to the E-Bus Ecosystem



- Comprehend the various types of hazards, categorisation of risk in E-Bus Ecosystem and their interconnections.
- Understand risk mapping and assessment framework tools to help cities evaluate vulnerabilities.

**Chapter 4**

Framework for E-Bus Hazard Resilience ecosystem


- Recognise the full spectrum of natural, technological & human induced hazards that affect e-buses, charging infrastructure, depots and the operating environment.
- See how event chain mapping demonstrates the way an initial hazard can trigger cascading disruptions across multiple system components.

**Chapter 5**

Hazard Specific Strategies for Predisaster, During Disaster and Post Disaster Recovery

- Assess potential risk and develop targeted preventive measures, response action & recovery plan for each hazard across all e-bus components.
- Walks through the three stages of disaster management: Pre-disaster during-disaster & post-disaster and aligns each stage with specific stakeholder roles.

## Part B: The E-Bus Disaster Readiness Blueprint

### Chapter 6

Pre-Disaster: Design and Planning Recommendations

- Define technical, safety, and performance standards for e-bus design, charging systems, and depot planning and operations, aligned with Indian regulatory frameworks (AIS, BIS, CMVR) and global benchmarks.
- Embed climate resilience, operational robustness, and technological reliability across the e-bus ecosystem—from procurement through long-term operations.
- Present planning and design recommendations covering electrical, thermal, structural, water ingress, cybersecurity, and other critical safety measures.
- Establish maintenance, inspection, and monitoring protocols to ensure sustained safety and performance.
- Strengthen operational excellence through continuous capacity-building, including crew and staff training, fire drills, and blended learning approaches.

### Chapter 7

During Disaster Strategies

- Implement an emergency response framework covering all identified hazards.
- Follow step-by-step, hazard-specific response protocols with clear SOPs for each target audience.
- Adopt rapid communication protocols to deliver timely updates to passengers, staff, and authorities during disasters.

### Chapter 8

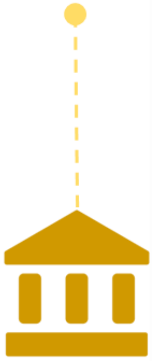
Post Disaster Strategies

- Implement standardized recovery and rehabilitation protocols for the e-bus ecosystem after hazardous events.
- Execute post-disaster actions including safety isolation, rapid impact assessments, inspections, interim restoration, repairs, verification, and insurance.
- Use a component-wise checklist to ensure thorough and consistent post-hazard evaluations.

## Part C: Enablers of E-Bus Resilience: People, Policies, and Preparedness

### Chapter 9

Institutional Backbone of the Disaster Response System



- Recognize the importance of a strong institutional framework to ensure climate-resilient and safe e-bus operations. Understand how fragmented responsibilities and weak linkages undermine effective disaster response.
- Implement a unified institutional architecture with clear roles, designated nodal agencies, escalation protocols, and inter-agency coordination pathways.

### Chapter 10

Capacity Development - Preparing Teams for E-Bus Disaster Response

- Strengthen training and capacity-building to ensure safe, reliable, and disaster-resilient e-bus operations.
- Conduct stakeholder-specific training for planners, policymakers, crew, depot staff, charging operators, grid engineers, ITMS teams, and first responders.

### Chapter 11

Financing Resilience - Smart Financing for Hazard-Proof E-Bus Systems

- Recognize financial resilience as a critical element for ensuring uninterrupted e-bus operations during and after disasters.
- Examine the unique financial vulnerabilities of e-bus systems and the key financing challenges that cities face.
- Implement targeted risk insurance mechanisms to protect critical assets from disaster-related damage.

### Chapter 12

Policy and Regulatory Recommendations

- Identify gaps in existing laws and standards to better cover EV-specific hazards such as battery fires, water ingress, and high-voltage system risks.
- Strengthen disaster management plans at national, state, and district levels by embedding EV-specific SOPs, improving inter-agency coordination, and defining emergency protocols.

# INTRODUCTION TO THE DOCUMENT

## I. Sustainable Urban Mobility- Air Quality, Climate Action and Accessibility (SUM-ACA) Program

The **Guidance Document on Building Resilient E-Bus Ecosystem** (EBES) has been developed under the Sustainable Urban Mobility – Air Quality, Climate Action and Accessibility (SUM-ACA) initiative, led by the Ministry of Housing and Urban Affairs (MoHUA) in partnership with GIZ under the Indo-German Green Urban Mobility Partnership.

The SUM-ACA initiative supports Indian cities in integrating climate action, air quality improvement, and sustainable mobility into urban transport planning. As part of this effort, this guidance document focuses on strengthening the resilience of EBES against natural, technological, and human-induced hazards.

## II. Overview of Guidance Document on Building Resilient E-bus Eco-System

The Guidance Document on Building Resilient EBES serves as a comprehensive reference for planning, designing, operating, and maintaining EBES capable of withstanding the impacts of spectrum of hazards - natural (floods, heatwaves, cyclones, earthquakes & landslides), technological (grid instability, battery failure, technological obsolescence and cyber threats), and human-induced (vandalism, accidents, human negligence/ lack of knowledge, personnel health and safety, capacity gaps). It addresses climate impacts, operational vulnerabilities, and institutional capacity gaps that can disrupt service continuity.

This guidance document lists practices in depot site selection, structural resilience, design resilience, drainage and flood protection, thermal comfort, fire safety, backup energy systems, security measures, and emergency response protocols amongst other. Integrating hazard preparedness with capacity building, institutional coordination, and financial planning, is expected to ensure that depots remain safe, functional, and reliable, even under adversities.

## III. Approach for Document

For a safe and efficient EBES operations, it is essential to understand and guard against potential hazards/ disruptions. This guidance document has been developed through a structured, multi-step process that draws learnings from Indian and international design standards, global case studies, and risk and vulnerability mapping, while integrating it with technical analysis, stakeholder input, and practical application as explained in the following exhibit. The evaluation covers all core component of EBES components, including the fleet (vehicles and batteries), depot (physical infrastructure), charging infrastructure (charging system and cables), and operating environment (enroute bus operations and surroundings).

Strategies are organised around preparedness, emergency response, and recovery, with emphasis on rapid restoration, service continuity, and learning for future improvement. The framework clearly maps these actions to the roles and responsibilities of the relevant stakeholders. To enable effective implementation, the document also highlights the importance of capacity building and training, clear institutional roles and coordination, financial resilience measures such as insurance and recovery financing with supportive policies and regulations.

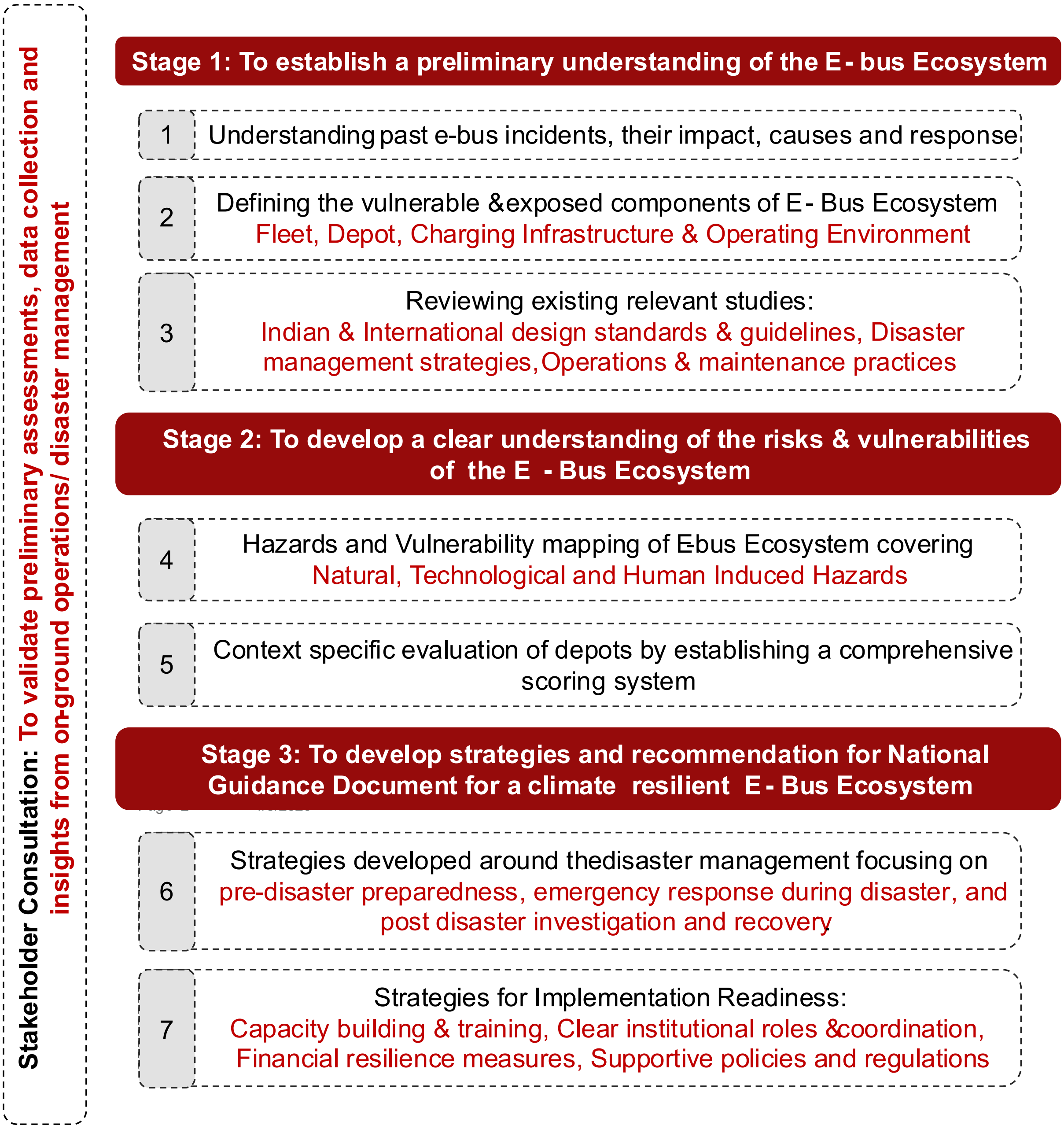



*Exhibit 10 Approach and Methodology for developing the Guidance Document*

Extensive consultations were undertaken with key stakeholders such as the Association of State Road Transport Undertakings (ASRTU) – an apex body of more than 50 State Transport Undertaking/ agencies (STUs), Bengaluru Municipal Transport Corporation (BMTC), Surat Municipal Corporation, Surat Sitilink Limited, Capital Region Urban Transport (CRUT) and Convergence Energy Solution Limited (CESL). These discussions provided valuable perspectives on operational challenges and existing disaster management practices within public bus transport agencies[3]. Consultations with leading Original Equipment Manufacturers (OEMs) further strengthened the process by bringing in perspectives on design standards and technical specifications. Additionally, representatives from the National Disaster Management Authority (NDMA), India Meteorological Department (IMD), fire departments, and other relevant agencies

[3] Public Bus Transport Agencies that manage public bus services in urban cities such as State Transport Undertaking (e.g. Karnataka State Road Transport Corporation), Municipal Transport Undertaking (e.g. Bengaluru Municipal Transport Corporation) and Special Purpose Vehicle (e.g. Sitilink, Surat).

contributed to the process, facilitating an exchange of knowledge and best practices across institutions.

Focus group discussion with multiple public bus transport agencies and National agencies enabled the consolidation of key themes, drawing on the practical insights from their operational experiences and highlighting critical gaps and challenges faced on ground. The Guidance Document is the culmination of these collective insights, reflecting a collaborative, multi stakeholder approach in strengthening disaster preparedness and resilience in the EBES.

## IV. Disclaimer

- This document is advisory in nature and not prescriptive. It does not replace or override existing laws, standards, and protocols and should be read and applied in conjunction with existing rules and standards, such as Central Motor Vehicle Rules (CMVR), Automotive Industry Standards (AIS), Bureau of Indian Standards (BIS), OEM manuals, guidance, and safety protocols, National Building Code (NBC), fire safety codes, relevant state and city-level regulations etc.
- This document provides high-level strategies and best practices but may not capture city-specific conditions such as climate, topography, infrastructure maturity, and institutional capacity. Accordingly, the advisory guidelines should be adapted to local contexts and customised by relevant public bus transport agencies and other stakeholders based on city-level vulnerabilities to different hazard types, including natural, technological, and human-induced hazards.
- The document is advisory in nature and provides indicative safety standards while outlining the role and responsibility of various stakeholders. The Standard Operating Procedures (SOPs) are designed based on a generic organisational structure within the e-bus ecosystem and should be customised to suit the specific organisational arrangements of each agency. The interpretation, application and adoption of these standards rest with the respective authorities and stakeholder within their jurisdiction.
- The guidance aims to be technology-neutral, but different e-bus models, battery chemistries, and charging technologies may require tailored measures beyond what the document prescribes. This guidance document has been developed based on technologies currently prevalent in the e-bus ecosystem, and any future technological advancements will necessitate appropriate customisation and periodic updates to the document.
- While the EBES may encompass additional elements, this document focuses on **four core components that are fleet, depot, charging infrastructure, and operating environment as relevant to hazard management.**

Hazards such as cybersecurity threats, technology failure, grid instability, and climate extremes are rapidly evolving and the range of hazards addressed in this document is not exhaustive. Accordingly, this guidance document should be periodically reviewed, updated and refined by the relevant agencies to incorporate emerging risks, new insights and lessons learned from practical experience.

## V. Reader's Guide: Roles and Relevant Section

This document has been designed to help stakeholders quickly navigate to the sections most relevant to their roles and responsibilities. While a comprehensive review of all sections is recommended to gain a holistic understanding of the e-bus ecosystem and hazard preparedness, teams may also choose to focus on sections specific to their functions. Each team or authority can directly refer to the indicated sections without reviewing the entire document. The table below maps each stakeholder group to its respective role and responsibility in this EBES.

*Table 1 Roles and responsibility of various stakeholder*

**List of Target Audience**

| Functions | Stakeholder | Role and Responsibility (E-Bus Related indicated here) |
|---|---|---|
| Planning & Procurement | Procurement Team | Plays a critical role in developing end-use requirement based technical specifications of e-buses and their sub-systems, sourcing, negotiating and managing the acquisition of e-buses and related services. Ensuring quality assurance and complainces with government regulation while translating operational needs into legally sound contracts that balance cost, safety, reliability and public accountability. |
| | Planning Team | Primalrily focus on strategic route planning, resource estimation, infrastructure planning and development and performance monitoring to esure efficient and safe public mobility. |
| | STU/Public Transport Authority | The role involves strategic management and operational oversight, managing and overseeing public bus services and the transition to e-buses. |
| | Civil/ Electrical Department | Responsible for planning, designing, and constructing depot infrastructure and facilities, ensuring safety and complaince with city's bye-laws. The electrical depoartment manages all electrical systems and power supply for the same. |
| Depot & Workshop | Depot & Central Workshop System | Manages day-to-day depot operations and serves as the technical and safety backbone of an e-bus depot. Their role extends beyond maintenance to include risk management, emergency response & continuous performance improvement. |
| | Charging System Provider | Optimises the charging schedules, tracking charger status, bus connections and ensures that the buses are operationally ready. The charging system provider performs preventive maintenance activities (of chargers, cables), diagnostics, repair and ensures safety. |
| | Technicians/ Electricians | Keeping e-buses operational by carrying out high voltage system diagnostics, battery maintenance, motor/inverter checks, charger upkeeps & routine servicing and safety assurance. |
| | DISCOM | Ensures reliable power supply and grid stability, supporting in setup of charging infrastructure and providing necessary power clearances to the e-bus depot. |
| Monitoring & Control | Control Room Team | Act as the central nervous system of operations by monitoring bus location, charging status and energy usages. Managing dispatch and addressing operational issues like route diversions, bus health monitoring, en-route emergencies and coordinating with driver and maintenance team to ensure delivery of punctual, reliable and safe passenger services. |
| | ITS Team | Provides real time monitoring of bus operations, assits in optmising charging schedules, dispatching e-buses efficiently and analysing data for performance improvement. |
| | Operations/ Technical Team | Monitors and oversees depot operations including energy management, fleet readiness, infrastructure health and driver support. Using ITS for real time tracking and operational data for battery health monitoring, range prediction and managing smooth day to day operations. |

| Functions | Stakeholder | Role and Responsibility (E-Bus Related indicated here) |
|---|---|---|
| Training & Safety | Safety Officer | Develops and delivers specialized training (high voltage, fire safety, new technology), conducts risk assessments and incident investigations, promotes a strong safety procedures for high-voltage components and charging infrastructure to ensure safe operation from charging through routine inspections. |
| | Capacity Building Team | Builds skills, knowledge & processes across officials, planners, engineers, drivers & mechanics to enable a smooth transition from conventional to e-buses, covering technical operations, charging infrastructure, procurement & operational management through tailored training & institutional capacity building. |
| Field Team | Drivers & Conductors | While drivers focus on safe, efficient e-bus operations on routes, managing the adavanced dashboards and driving mechanics. The conductors handle passenger services like ticketing and communications. |
| Emergency Services | First Responders | First responders such as police, fire services, and ambulance team, continue to perform their roles with additional responsibility and precautions required to address the high-voltage systems & lithium-ion batteries specific to e-buses. |
| Private Player | OEM | Responsible for designing, manufacturing and integrating advanced technologies pertaining to batteries, motors and software, while ensuring quality, providing maintenance & warranty support. OEMs also collaborate with public bus transport agencies and Public Private Partenership (PPP) bus opertaors to develop customised solutions that enable safe, efficient, and sustainable e-bus operations. |

Part A of the Guidance Document, outlines the need for a resilient EBES, defines resilience in EBES, contextualises its four components, and presents the risk landscape. It then builds the foundation for the E-Bus Hazard Resilience Framework, detailing strategies across pre-disaster, during-disaster, and post-disaster phases. This section is relevant to all stakeholders involved in planning, operating, regulating, and supporting e-bus systems. It establishes a common risk vocabulary, hazard typologies, assessment framework for vulnerability and exposure, and system-level understanding that underpin a disaster-resilient ecosystem. All readers are strongly encouraged to review Part A, as it forms the basis for the hazard-specific guidance, Standard Operating Procedures (SOPs), and actionable recommendations in the subsequent sections. Given that the roles and responsibility vary across stakeholders, the following table provides a quick navigation to the relevant sections from Part B onwards of the document.

*Table 2 Readers Guide to relevant sections*

| Target Audience | Reference Sections | | | Relevance |
|---|---|---|---|---|
| | Pre-Disaster Planning: Chapter 6 | During - Disaster Planning: Chapter 7 | Post - Disaster Planning: Chapter 8 | |
| Planning Team | **Planning and design recommendations:**<br>*Section: 6.1 (Fleet), 6.2 (Depot), 6.3 (Charging Infrastructure), 6.4 (Operating Environment)*<br>○ Electrical safety<br>○ Water ingress protection. | - | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities), 8.1.1 (Post Hazard Interim Restoration of service Action Plan)*<br>○ Interim Restoration of Services | ✓ Informs resilient site selection, layout, and infrastructure design.<br>✓ Emphasizes redundancy and backup provisions for critical systems. |

| Target Audience | Reference Sections | | | Relevance |
|---|---|---|---|---|
| | Pre-Disaster Planning: Chapter 6 | During - Disaster Planning: Chapter 7 | Post - Disaster Planning: Chapter 8 | |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Module 8: Policy Oversight & Coordination)*<br>**Chapter 11. Financing Resilience**<br>*Section 11.2 (Role of Risk Insurance Mechanism)*<br>**Chapter 12. Policy and Regulatory Recommendations**<br>*Section 12.5 (Procurement)* | | | ✓ Encourages integration of monitoring and early warning mechanisms.<br>✓ Aligns planning practices with national safety and resilience standards.<br>✓ Supports resource allocation and budgeting for long-term resilience. |
| **Procurement Team** | **Planning and design recommendations:**<br>*Section: 6.1 (Fleet), 6.3 (Charging Infrastructure), 6.4 (Operating Environment)*<br>○ Electrical safety<br>○ Water ingress protection.<br>○ Structural Safety<br>○ Thermal Safety<br>○ Cyber Safety | - | - | ✓ Embed resilience and safety in bid specifications.<br>✓ Ensure compliance with AIS/BIS/CEA standards.<br>✓ Select certified, reliable equipment.<br>✓ Define vendor responsibility for safety and recovery support.<br>✓ Evaluate on lifecycle resilience, not just cost.<br>✓ Include warranty, spares, and continuity clauses.<br>✓ Coordinate with planning and O&M teams for alignment |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 11. Financing Resilience**<br>*Section 11.2 (Role of Risk Insurance Mechanism)*<br>**Chapter 12. Policy and Regulatory Recommendations**<br>*Section 12.5 (Procurement)* | | | |
| **Depot & Central Workshop System** | **Planning and design recommendations:**<br>*Section: 6.1 (Fleet), 6.2 (Depot), 6.4 (Operating Environment)*<br>○ Electrical safety<br>○ Water ingress protection.<br>○ Structural Safety<br>○ Thermal Safety<br>○ Cyber Safety | **During Disaster Strategies:**<br>*Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet & Depot Operations Protocol*<br>○ Flood/ Cyclone/ Heavy Rains/ Thunderstorm<br>○ Earthquake<br>○ Heatwaves<br>○ Grid Instability | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities)*<br>○ Immediate Isolation for safety & Securing Sites<br>○ Rapid impact & safety assessment<br>○ Technical Specification & Diagnostic<br>○ Interim Restoration of service | ✓ Recommendations on various planning and design strategies for the infrastructure/ assets in the depot<br>✓ Ensure compliance with AIS/BIS/IEC standards.<br>✓ Ensure resilience through various response protocols & SOPs |

| Target Audience | Reference Sections | | | Relevance |
|---|---|---|---|---|
| | Pre-Disaster Planning: Chapter 6 | During - Disaster Planning: Chapter 7 | Post - Disaster Planning: Chapter 8 | |
| | | ○ Battery Failure<br>○ Cyber Threat<br>○ Technological Obsolescence<br>○ Protest & Vandalism<br>○ Accidents & Collisions<br>○ Knowledge Gaps/ Management Lapse<br>○ Emergency Energy Management<br>○ Planned Energy Management<br>○ Staff & Passenger Safety SOP for first responder<br>○ Safe Evacuation of staff/ Passenger<br>○ Damage & Safety Checks | ○ SOP revision, institutional strengthening<br>*8.1.1 (Post Hazard Interim Restoration of service Action Plan)*<br>○ Interim Restoration of Services | to manage crisis wherever depot manager / depot staff is required<br>✓ Define steps for the rapid impact assessment, revision of technical specifications and diagnostic mechanism that is needed to be done post disaster.<br>✓ Coordinate with planning and safety officer for alignment and safety checks |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 9. Institutional Backbone**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Mapping of Training Needs for various stakeholder)* | | | |
| **Charging System Provider** | **Planning and design recommendations:**<br>*6.3(Charging Infrastructure)*<br>○ Electrical safety<br>○ Water ingress protection.<br>○ Structural Safety<br>○ Thermal Safety<br>○ Cyber Safety<br>○ General Safety Measures | **During Disaster Strategies:**<br>*Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Depot Operations Protocol*<br>○ Flood/ Cyclone/ Heavy Rains/ Thunderstorm<br>○ Heatwaves<br>○ Grid Instability<br>○ Battery Failure<br>○ Emergency Energy Management | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities)*<br>○ Technical Specification & Diagnostic | ✓ Recommendations on various planning and design strategies for the charging infrastructure<br>✓ Ensure compliance with AIS/IS/IEC standards and other relevant international standards.<br>✓ Build in redundancies as alternative sources of energy supply<br>✓ Ensure resilience through various response protocols & SOPs to manage crisis due to natural and technological hazards related to |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Module 4: Charging Infrastructure Operations. Module 5: Grid Coordination & Emergency Response)* | | | |

| Target Audience | Reference Sections | | | Relevance |
|---|---|---|---|---|
| | Pre-Disaster Planning: Chapter 6 | During - Disaster Planning: Chapter 7 | Post - Disaster Planning: Chapter 8 | |
| | | | | charging infrastructure<br>✓ Define steps for the technical specification and diagnostic that is needed to be done post disaster.<br>✓ Builds resilience through imparting training on charging infrastructure operations, grid coordination |
| **Technicians/ Electricians** | **Planning and design recommendations:**<br>*6.1(Fleet), 6.2 (Depot) 6.3(Charging Infrastructure),*<br>○ Maintenance Activities<br>○ Relevant Capacity building system wrt above. | **During Disaster Strategies:**<br>*Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Depot Operations Protocol*<br>○ Flood/ Cyclone/ Heavy Rains/ Thunderstorm<br>○ Heatwaves<br>○ Grid Instability<br>○ Battery Failure<br>○ Protest/ Vandalism<br>○ Knowledge Gaps/ Management Lapse<br>○ Emergency Energy Management<br>○ Planned Energy Management<br>○ Staff & Passenger Safety SOP for first responders<br>○ Safe Evacuation of Staff/ Passenger<br>○ Damage & Safety Checks | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities)*<br>○ Rapid Impact & Safety Assessment<br>○ Technical Specification & Diagnostic<br>○ Repair, Recommission & Testing<br>○ Verification, Documentation & Third-Party Clearance<br>○ SOP revision, institutional strengthening & Capacity Building | ✓ Resilience through informed day to day activities/ maintenance schedules that needs to be undertaken<br>✓ Emphasizes on the role and actions needed to be taken during any disasters<br>✓ Supports in rapid impact assessment, verification and documentation post disaster. |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Module 1: Driver Safety & Emergency Response; Module 2: Technical & Maintenance Safety; Module 4: Charging Infrastructure Operations; Module 7: Fire Management & Coordination)* | | | |
| **DISCOM** | **Planning and design recommendations:** | - | **Post Disaster Activities:** | ✓ various approvals that need to be |

<table>
<tr><th rowspan="2">Target Audience</th><th colspan="3">Reference Sections</th><th rowspan="2">Relevance</th></tr>
<tr><th>Pre-Disaster Planning: Chapter 6</th><th>During - Disaster Planning: Chapter 7</th><th>Post - Disaster Planning: Chapter 8</th></tr>
<tr><td rowspan="2"></td><td>6.2(Depot) 6.3(Charging Infrastructure)<br>- Electrical Safety<br>- Common Safety Measure<br>○ Approval & Sanctions Required<br>○ Grid Resilience<br>○ Resilient Upstream Infrastructure</td><td></td><td>Section: 8.1 (Post Disaster Activities)<br>○ Technical Specification & Diagnostic</td><td rowspan="2">undertaken for adequate power supply line<br>✓ Informs about resilient upstream infrastructure.<br>✓ Integration of alternative energy sources<br>✓ Encourage integration of monitoring and early warning mechanisms.<br>✓ Recommendations on aligning planning practices with disaster management framework.</td></tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 10. Capacity Development<br>Section 10.1 (Module 5: Grid Coordination and Emergency Response)<br>Chapter 12. Policy and Regulatory Recommendations<br>Section 12.2 (Disaster Management Framework)</td></tr>
<tr><td rowspan="2">Control Room Team</td><td>Planning and design recommendations:<br>6.1(Fleet), 6.4(Operating Environment),<br>○ Monitoring</td><td>During Disaster Strategies:<br>Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet & Depot Operations Protocol<br>○ Flood/ Cyclone/ Heavy Rains/ Thunderstorm<br>○ Earthquake<br>○ Heatwaves<br>○ Battery Failure<br>○ Protest/ Vandalism<br>○ Accidents/ Collision</td><td>-</td><td rowspan="2">✓ Ensures integrated transmission of information to the depot for any kind of disaster.<br>✓ Supports in monitoring various ITS systems and help in detecting any anomaly.</td></tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 10. Capacity Development<br>Section 10.1 (Module 6: ITMS & Control Room Emergency)</td></tr>
<tr><td>ITS Team</td><td>Planning and design recommendations:<br>6.1(Fleet), 6.3(Charging Infrastructure),<br>- Cyber Threat<br>- Monitoring<br>- General Safety Measure<br>○ Battery Related Safety Sensors</td><td>During Disaster Strategies:<br>Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet & Depot Operations Protocol<br>○ Cyber Threat<br>○ Technological Obsolescence</td><td>Post Disaster Activities:<br>Section: 8.1 (Post Disaster Activities)<br>○ Technical Specification & Diagnostic<br>○ Repair, Recommission & Testing</td><td>✓ Ensures safety against cyber threat to various components of fleet and charging infrastructure<br>✓ Supports in monitoring various battery related sensors, ITMS and</td></tr>
</table>

| Target Audience | Reference Sections | | | Relevance |
|---|---|---|---|---|
| | Pre-Disaster Planning: Chapter 6 | During - Disaster Planning: Chapter 7 | Post - Disaster Planning: Chapter 8 | |
| | ○ Safety from Technological Obsolescence | | | help in detecting any anomaly. |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Module 6: ITMS & Control Room Emergency)* | | | |
| **Operations/ Technical Team** | **Planning and design recommendations:**<br>*6.1(Fleet), 6.2 (Depot), 6.4(Operating Environment),*<br>○ Planning & Design Standards<br>○ Maintenance Activities<br>○ Monitoring | **During Disaster Strategies:**<br>*Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet & Depot Operations Protocol*<br>○ Accidents/ Collision | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities), 8.1.1 (Post Hazard Interim Restoration of service Action Plan)*<br>○ Interim Restoration of Services | ✓ Supports in planning and executing day to day activities like maintenance and operations of PT Services<br>✓ Ensures real time monitoring various battery related and other performance parameters, through ITMS and help in delivering reliable, punctual and safe passenger transport services.<br>✓ Effectively activates action plans to quickly carryout rescue operations and restore essential city services. |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Module 3: Technical & Maintenance Safety)* | | | |
| **Safety Officer** | **Planning and design recommendations:**<br>*6.1(Fleet), 6.2 (Depot), 6.3(Charging Infrastructure 6.4(Operating Environment),*<br>○ Planning & Design Standards<br>○ Inspection | **During Disaster Strategies:**<br>*Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Depot Operations Protocol*<br>○ Earthquake<br>○ Heatwaves<br>○ Battery Failure<br>○ Knowledge Gaps/ Management Lapse<br>○ Emergency Energy Management<br>○ Planned Energy Management<br>○ Safe Evacuation of Staff/ Passenger | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities)*<br>○ Rapid Impact & Safety Assessment<br>○ Repair, Recommission & Testing | ✓ Supports in developing safety system, facilitates and the SOPs, conducting inspection and safety audits of the assets.<br>✓ Overview of the proposed safety-support structure under the CTSO<br>✓ Role and responsibility for hazard detection, fire suppression and post-accident handling.<br>✓ Supports coordination mechanism with fire department, |

<table>
<tr><th>Target Audience</th><th colspan="3">Reference Sections</th><th>Relevance</th></tr>
<tr><td></td><td>Pre-Disaster Planning: Chapter 6</td><td>During - Disaster Planning: Chapter 7</td><td>Post - Disaster Planning: Chapter 8</td><td></td></tr>
<tr><td rowspan="3">Capacity Building Team</td><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 9. Institutional Backbone<br>Chapter 10. Capacity Development<br>Section 10.1 (Module 7: Fire Management & Coordination)</td><td>Disaster management authority, OEMs and control centre during disasters and rescue operations</td></tr>
<tr><td>Planning and design recommendations:<br>6.1(Fleet), 6.2 (Depot), 6.3(Charging Infrastructure 6.4(Operating Environment),<br>- General Safety Measure<br>o Capacity Building<br>- Capacity Building & Training</td><td>During Disaster Strategies:<br>Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) –Training & Simulation SOPs</td><td>Post Disaster Activities:<br>Section: 8.1 (Post Disaster Activities)<br>o SOP Revision, Institutional Strengthening & Capacity Building<br>o Training & Simulations SOPs</td><td rowspan="2">✓ Mapping role-specific training needs and developing training modules for all stakeholder and user groups.<br>✓ Guidance on designing audit training, compliance training and inter-agency SOPs</td></tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 10. Capacity Development</td></tr>
<tr><td rowspan="2">Drivers & Conductors</td><td>Planning and design recommendations:<br>Section: 6.4 (Operating Environment)<br>o General Safety Measures<br>o Training & Capacity Building</td><td>During Disaster Strategies:<br>Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet Operations Protocol<br>o Flood/ Cyclone/ Heavy Rains/ Thunderstorm<br>o Earthquake<br>o Heatwaves<br>o Battery Failure<br>o Protest & Vandalism<br>o Accidents & Collisions<br>o Knowledge Gaps/ Management Lapse<br>o Staff & Passenger Safety SOP for first responder<br>o Safe Evacuation of staff/ Passenger</td><td>Post Disaster Activities:<br>Section: 8.1 (Post Disaster Activities)<br>o Immediate isolation for safety & securing sites</td><td rowspan="2">✓ Focuses on capacity building and training crews in preventive strategies at planning stages to enhance preparedness and reduce human-induced hazards.<br>✓ Prepare crew in early identification of hazard signals, effective use of fire extinguishers, hazard specific perceptive/ safe driving techniques, detection of any electrical fault and in safe implementation of post collision actions.<br>✓ Also brings out details of refresher courses for re-training the drivers & the conductors.</td></tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 10. Capacity Development<br>Section 10.1 (Module 1: Driver Safety & Emergency Response)</td></tr>
</table>

<table>
<tr><th rowspan="2">Target Audience</th><th colspan="3">Reference Sections</th><th rowspan="2">Relevance</th></tr>
<tr><th>Pre-Disaster Planning: Chapter 6</th><th>During - Disaster Planning: Chapter 7</th><th>Post - Disaster Planning: Chapter 8</th></tr>
<tr>
<td rowspan="2">First Responders</td>
<td>Planning and design recommendations:<br>6.1(Fleet), 6.2 (Depot), 6.3(Charging Infrastructure 6.4(Operating Environment),<br>○ Monitoring<br>○ Training</td>
<td>During Disaster Strategies:<br>Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet Operations Protocol<br>○ Staff & Passenger Safety SOP for first responder<br>○ Safe Evacuation of staff/ Passenger</td>
<td>Post Disaster Activities:<br>Section: 8.1 (Post Disaster Activities)<br>○ Immediate isolation for safety & securing sites</td>
<td rowspan="2">✓ Focuses on planning for evacuation of depot staff and isolation of assets; and evacuation of onboarded passengers and safe isolation of the e-bus.<br>✓ Explains in detail about the role and responsibility of crew during a disaster</td>
</tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 10. Capacity Development<br>Section 10.1 (Module 2: Depot Incident Response & Risk Management; Module 6: ITMS & Control Room Emergency Monitoring)</td></tr>
<tr>
<td rowspan="2">OEM</td>
<td>Planning and design recommendations:<br>Section: 6.1 (Fleet), 6.2 (Depot), 6.3 (Charging Infrastructure)<br>○ Electrical safety<br>○ Water ingress protection.<br>○ Structural Safety<br>○ Thermal Safety<br>○ Cyber Safety<br>○ General Safety Measures<br>○ Inspection<br>○ Monitoring</td>
<td>During Disaster Strategies:<br>Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Fleet & Depot Operations Protocol<br>○ Cyber Threat<br>○ Accident/ Collision</td>
<td>Post Disaster Activities:<br>Section: 8.1 (Post Disaster Activities)<br>○ Rapid Impact & Safety Assessment<br>○ Technical Specification & Diagnostic<br>○ Repair, Recommission & Testing<br>○ Verification, Documentation & Third-Party Clearance<br>○ SOP revision, institutional strengthening</td>
<td rowspan="2">✓ Responsibility for a resilient e-bus design and for safety coordination (battery handling, charging safety, fire prevention)<br>✓ Participation in inspection, failure analysis , post disaster restoration and certification activities.</td>
</tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 10. Capacity Development<br>Section 10.1 (Module 7: Fire Management & Coordination)</td></tr>
<tr>
<td rowspan="2">STU/ Public Transport Authority</td>
<td>-</td>
<td>-</td>
<td>Post Disaster Activities:<br>Section: 8.1 (Post Disaster Activities)<br>○ Long Term Resilience Upgrades</td>
<td rowspan="2">✓ Integrate resilience and safety into bid specifications.<br>✓ Ensure inclusion of monitoring and early warning systems.<br>✓ Aligns planning practices with national safety</td>
</tr>
<tr><td colspan="3">Other Reference Sections: Enabling Measures<br>Chapter 9. Institutional Backbone<br>Chapter 10. Capacity Development<br>Chapter 11. Financing Resilience</td></tr>
</table>

| Target Audience | Reference Sections | | | Relevance |
|---|---|---|---|---|
| | Pre-Disaster Planning: Chapter 6 | During - Disaster Planning: Chapter 7 | Post - Disaster Planning: Chapter 8 | |
| | **Chapter 12. Policy & Regulatory Recommendations** | | | and resilience standards.<br>✓ Supports resource and budget allocation for long-term resilience. |
| **Civil/ Electrical Department** | **Planning and design recommendations:**<br>*Section: 6.2 (Depot)*<br>○ Electrical safety<br>○ Water ingress protection.<br>○ Structural Safety<br>○ Thermal Safety<br>○ Cyber Safety<br>○ General Safety Measures<br>○ Maintenance | **During Disaster Strategies:**<br>*Section: 7.1 (Communication Protocol), 7.2 (Detail Emergency Protocols & SOPs) – Depot Operations Protocol*<br>○ Flood/ Cyclone/ Heavy Rains/ Thunderstorm<br>○ Battery Fires | **Post Disaster Activities:**<br>*Section: 8.1 (Post Disaster Activities)*<br>○ Technical Specification & Diagnostic<br>○ Verification, Documentation & Third-Party Clearance | ✓ Informs about/ builds in various structural and electrical design and standards that need to be incorporated while designing and planning of a depot, upstream power supply and substation, charging infrastructure etc.<br>✓ Supports in post disaster restoration and documentation. |
| | **Other Reference Sections: Enabling Measures**<br>**Chapter 10. Capacity Development**<br>*Section 10.1 (Module 3: Technical & Maintenance Safety, Module 4: Charging Infrastructure Operations, Module 5: Grid Coordination and Emergency Response)* | | | |

**PART A:**

# Setting the Charge: Building a Resilient Future for E-Bus Infrastructure

# 1. NEW AGE MOBILITY – UNLOCKING POTENTIAL WITH RESILIENCE

The global shift towards sustainable mobility has made e-buses a cornerstone of decarbonising urban transport. E-buses are also at the forefront of India's sustainable mobility transformation wherein the country is reducing carbon emissions and fossil fuel dependency to reach its Net Zero emissions goal by year 2070. Government of India is spearheading the transformation through conducive schemes such as 'PM Electric Drive Revolution in Innovative Vehicle Enhancement. (PM-EDRIVE)', 'Faster Adoption and Manufacturing of Electric Vehicles (FAME I & II)', 'National Electric Bus Program (NEBP)' and PM E-Bus Sewa. Over 11,300 e-buses ply across Indian cities as of January 2026[4]. While the number of e-buses on road burgeon, Indian cities are also witnessing significant expansion of complex EBES spanning from high-voltage power distribution system, e-bus fleets, digitally managed charging systems, interconnected depots and associated need for skilled workforce.

Over the years this complex ecosystem was observed to be sensitive to range of hazards such as extreme weather, grid instability, cybersecurity breaches and mishaps. Each hazard can trigger cascading failures affecting safety, operational reliability, and erode public confidence. To ensure a safer and sustainable transition to e-buses, there is an urgent need for designing the ecosystem to prevent and withstand disruptions from natural disasters to technological failures and human-induced incidents.

## 1.1. Why Building Resilience matters for E-buses

E-buses offer significant advantages including higher energy efficiency, reduced dependence on fossil fuel, lower local air pollution, and significantly minimised vibration and noise offer an advanced solution for decarbonisation. As more Indian cities shift to the e-buses, new safety and operational challenges are emerging. With prevalence of high-capacity lithium-ion batteries and HV systems, safety risks such as fire hazards, thermal runaway, and HV system failures are expected to escalate over time. The EBES being nascent, also faces constraints such as limited supply chains, expensive assets, and a shortage of specialised technical knowledge and training among crew and maintenance personnel. Furthermore, climate change exacerbates these vulnerabilities, with rising temperatures and extreme weather events like heatwaves, flooding, and storms posing additional threats to system reliability.

Unlike ICE systems that are more standalone and less susceptible to cascading failures, e-bus systems require an integrated, resilient approach to manage interconnected risks across e-buses, charging infrastructure, and operations. The complex interplay of high-voltage systems, thermal runaway, battery malfunctions including over-charge and over discharge, short circuits, collisions and climate-induced risks presents significant challenges.

Growing reports of e-bus fires, accidents, and service delays both globally and in India as illustrated in Exhibit 11 clearly demonstrate these risks. Several incidents reported in Shenyang (China), Stuttgart (Germany), Paris (France), and Ahmedabad (India) indicate that fires often originate during depot charging or due to undetected battery degradation. These events have resulted in substantial fleet damage, injuries, and fatalities, exposing gaps in battery safety protocols, thermal management, charging controls, and fire-resilient depot design.

Environmental factors have also been reported in the public domain as contributors to operational challenges in EBES. For Instance, publicly reported experience from Oslo (Norway)[5] that extreme

[4] Vahan Dashboard, MoRTH
[5] Oslo Norway, 2023

cold temperatures severely affected battery performance, leading to a complete suspension of e-bus services. Conversely, media and industry reports from cities such as Bengaluru (India)[6] and Shenzhen (China)[7] have highlighted instances where flooding and water ingress into battery and electrical systems in cities have disrupted operations, underscoring the vulnerability of e-bus systems to climatic extremes and the need for weather-resilient technologies and infrastructure. Human-induced risks further intensify these challenges. In addition, publicly reported incident including a fatal accident in Mumbai (India)[8] have drawn attention to human induced risks, where gaps in driver training and operational preparedness were cited as contributing factors. Such cases reinforce the need for structured capacity building programmes, clearly defined operational SOPs, deployment of advanced driver assistance systems, and continuous monitoring to support safe and reliable e-bus operations.

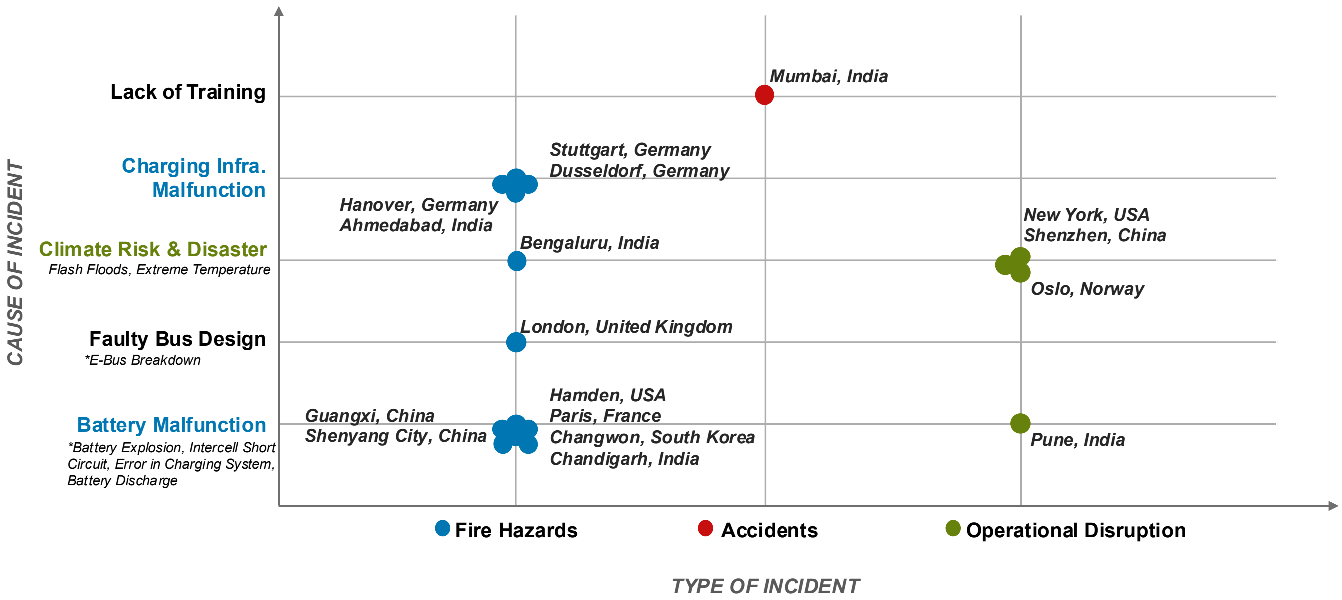



*Exhibit 11 Past E-Bus Incidents and Accidents (*This is not an exhaustive list)*

These examples represent only a subset of risks that have been reported in the public domain; many similar incidents have occurred globally. Such risks underscore the need for proactive measures to prevent and mitigate potential fire hazards, risks of electrocution, physical damage, and disruptions in operations. Therefore, building resilience into e-bus systems is not just a technical necessity but a strategic imperative to safeguard investments, ensure passenger safety, maintain service continuity, and fully realise the economic and environmental benefits of e-buses.

## 1.2. Enabling a Proactive and Integrated framework for a Resilient E-Bus Ecosystem

Until now, guidance on e-bus disaster response in India has been fragmented, incident-specific, and reactive. This national document attempts to address following inter-related complexities:

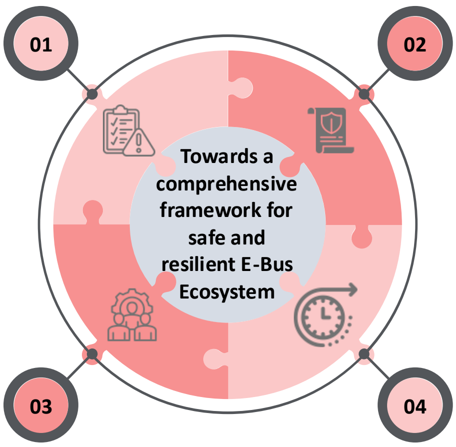
[6] Bengaluru India, 2024
[7] Shenzen China, Electric bus fleets during urban flash floods: A mixed bus fleet strategy, 2025
[8] Mumbai, India 2024

**Managing Risks that have potential to trigger cascading hazards**

With the increasing deployment of e -buses across more than 50 cities, operational challenges arising from floods and other natural disasters, battery failure, grid instability, technology obsolescence and cyber threats require necessitate a proactive and systematic response.

**Operational Continuity**

Needed to protect public trust in e -bus systems during operations.




**Closing Policy Gaps**

Existing transport safety codes, standards and policies provide limited coverage of the unique vulnerabilities of electric mobility. This document aligns national and international best practices to strengthen the policy framework.

**Futureproofing**

Urgency for future -proofing EBES by building adaptability for emerging hazards such as battery technology failures or climate extremes and systems for advanced skilling.

*Exhibit 12 Objectives towards building a resilient e-bus ecosystem guidance*

This document bridges the gaps through a **practical blueprint** for nation-wide hazard mapping, design measure's consolidation, response coordination, and recovery of EBES.

# 2. Context for a System Level Framework for Resilient E-Bus Ecosystem

A resilient EBES relies on an integrated framework that ensures safety, reliability and continuity across all operations. It reflects the inherent ability of the interconnected components including e-buses, charging infrastructure, depot, operating environment and the supporting power grid to withstand, adapt to and rapidly recover from the disruption. Together, these elements play distinct yet interdependent roles in maintaining system performance under both normal and stressed conditions. The following exhibits presents the four key principles of EBES resilience.

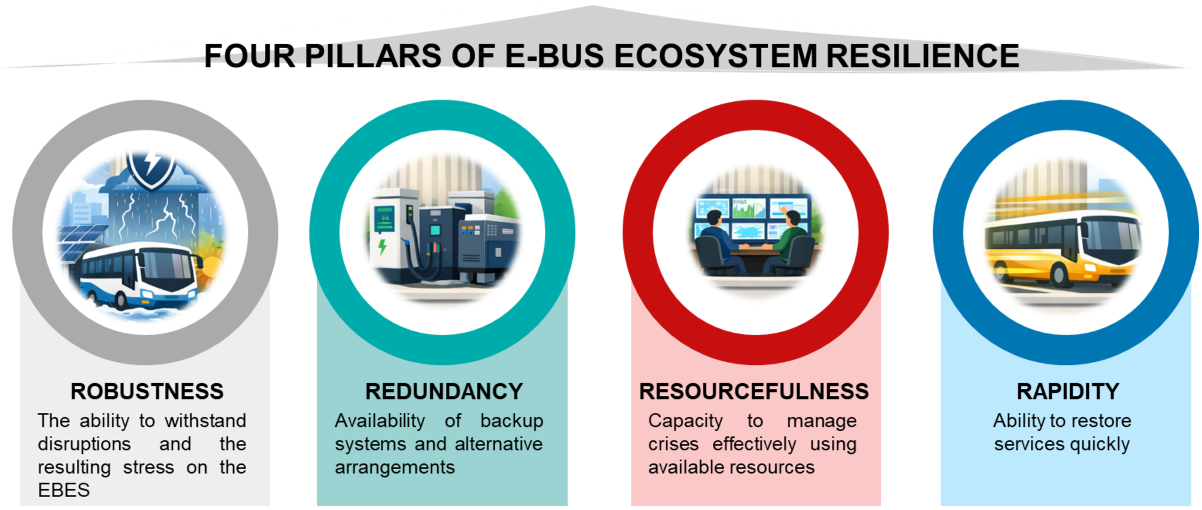



*Exhibit 13 Four pillars of E-Bus Ecosystem resilience*

## 2.1. The Four Components of the E-Bus Ecosystem

A resilient EBES stands on four interconnected components: **Fleet, Depot, Charging Infrastructure, Operating Environment.**

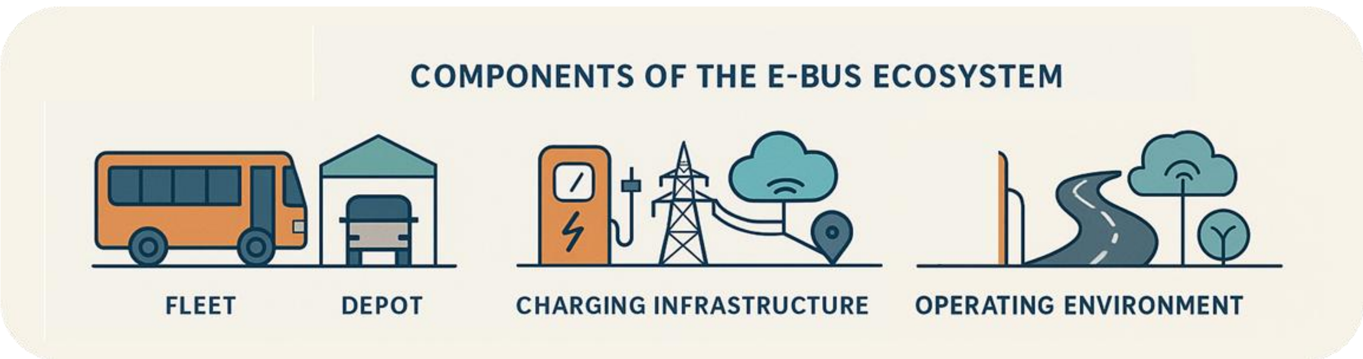



*Exhibit 14 Four different components of the E-Bus Ecosystem*

Key considerations for each EBES components include-

**1. Fleet –** Resilience of an e-bus depends on factors such as vehicle body design, battery placement, operating range, thermal management, and onboard safety systems. Since the fleet is the primary point of service delivery, ensuring its reliability is fundamental to maintaining uninterrupted operations.

**2. Depot –** Depot's act as the operational backbone, supporting parking, maintenance, battery storage and administration. Their concentration of vehicles, equipment, and depot staff makes them highly vulnerable to hazards like fire, heatwaves, flooding, or seismic events. Considerations such as safe design, layout efficiency, and protective infrastructure are essential for safeguarding both assets and workforce.

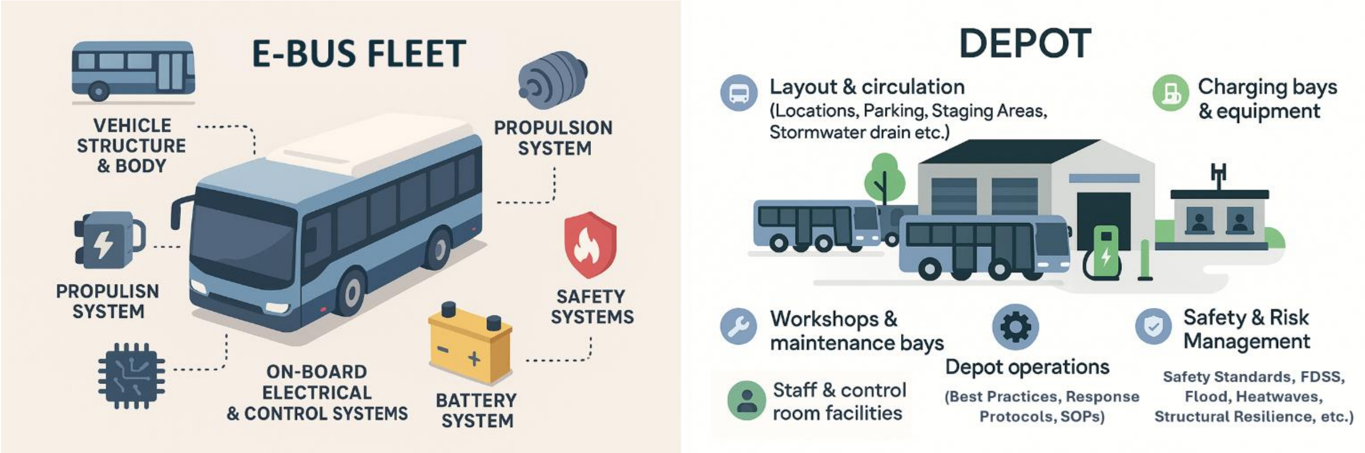



*Exhibit 15 Components of the E-Bus System: E Bus Fleet and Depots*

**3. Charging Infrastructure –** Charging systems provide the energy lifeline for the fleet, encompassing chargers, substations, transformers, cabling, and energy management software. Any disruption directly impacts service delivery. Building resilience requires redundancy, safety standards for the staff, cyber security, safety mechanisms, and stable grid connections to ensure consistent availability of charging.

**4. Operating Environment –** The operating environment covers the broader urban ecosystem including roads, corridors, stations, passengers, crew and enroute road users and supporting IT systems. It is further influenced by climatic conditions, regulatory frameworks, and institutional capacities. Strengthening resilience here ensures safety of people and the delivery of efficient and reliable public transport services, even during disruptions.

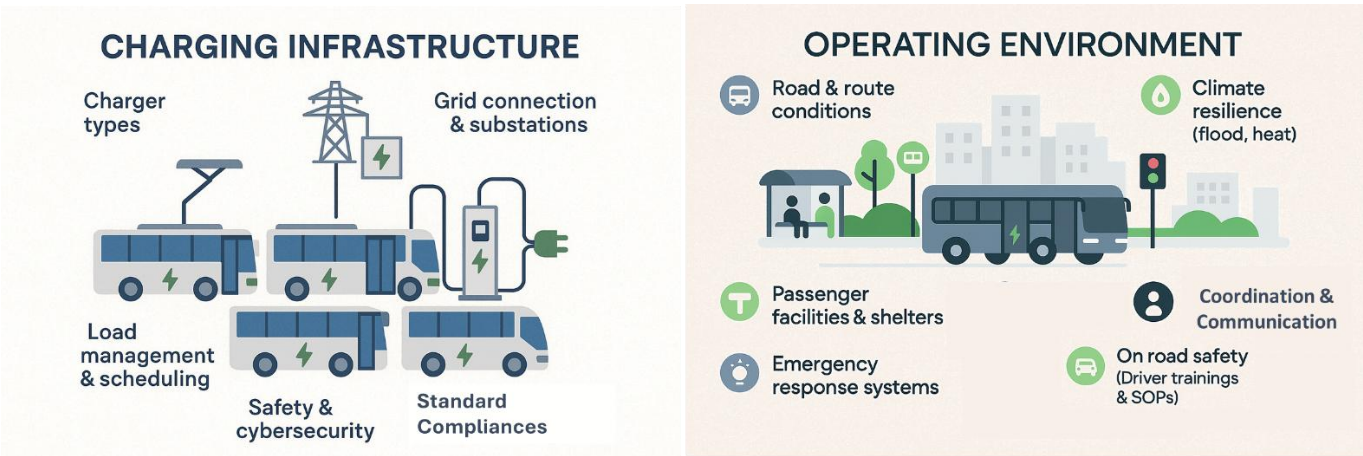



*Exhibit 16 Components of the E-Bus System- Charging Infrastructure and Operating Environment*

***Note:** The EBES though compromises of other aspects, this document focuses on the above four components due to their significance to hazards.*

For each of the components outlined above, the guidance document provides structured recommendations across the **pre-disaster, during-disaster, and post-disaster** phases, as detailed in the following sections.

## 2.2. Intended Users

The document is intended for use by a wide range of stakeholders involved in planning, operating, and safeguarding EBES, including but not limited to the following:

- **Public Transport Agencies and Operators –** For daily operations and emergency readiness.
- **Infrastructure Developers and Engineers –** For depot and charging station design and safety planning.
- **OEMs and Technology Providers–** For product design and incorporating hazard-resistant features.
- **Disaster Management Authorities–** For inclusion in urban emergency management frameworks.
- **Fire Department-** For inclusion of targeted fire safety provisions and involvement in EBES.
- **Policymakers and Regulators –** For developing technical standards and safety compliance measures, policies and regulations.
- **Urban Transport Planners and Consultants –** For integrating resilience in project designs.

*Exhibit 17 About the Intended Users*

# 3. Navigating the Risk Landscape: Mapping Impacts to the E-Bus Ecosystem

## 3.1. Categories of Risks in the E-Bus Ecosystem

EBES face a diverse array of risks that can disrupt operations, compromise safety, and lead to financial losses. These risks are classified into three categories: **Natural Hazards**, arising from environmental and climatic events; **Technological Hazards**, stemming from design failures in electrical power supply system, battery, digital systems and technological failure; and **Human-induced Hazards**, due to knowledge gaps/ capacities and management lapse encompassing accidental and operational disruptions.

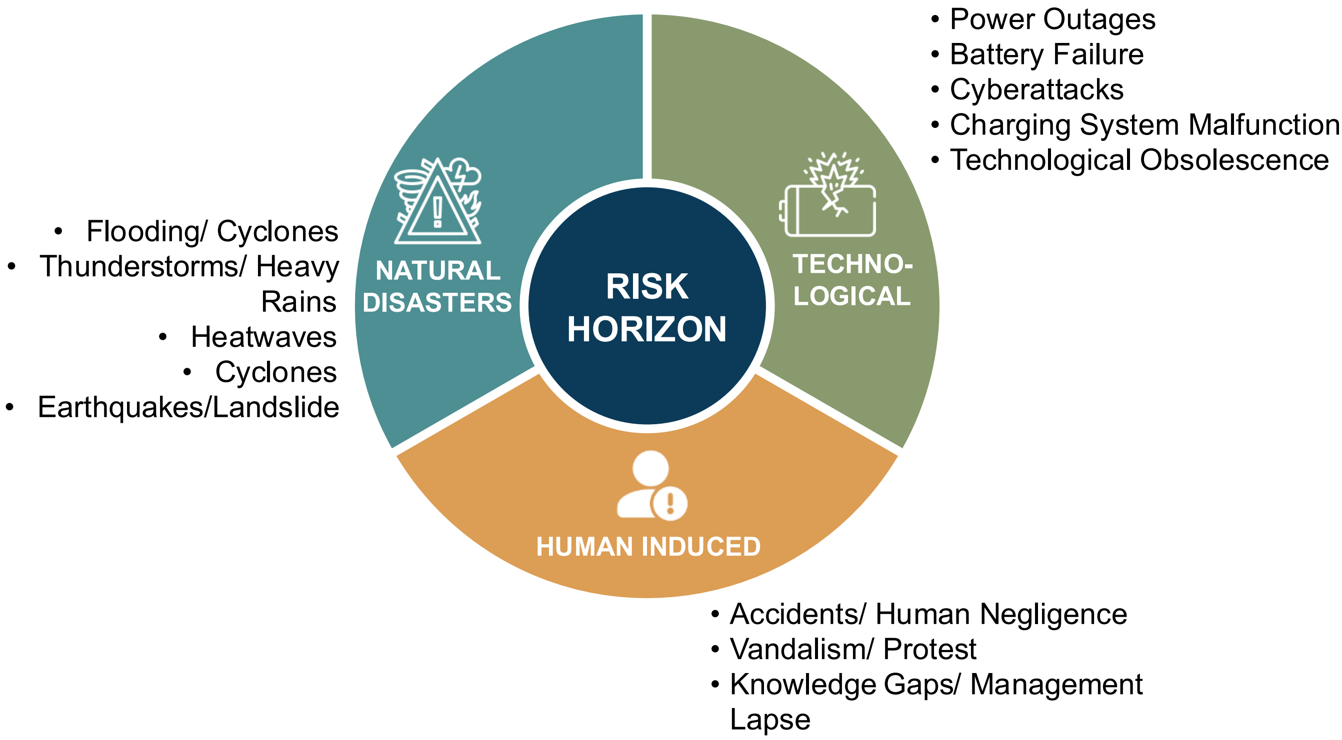



*Exhibit 18 Hazard categories for E-Bus ecosystem*

In an EBES, hazards rarely occur in isolation. A single disruptive event can trigger cascading failures across multiple components. Given the high interdependencies between fleet, depots, charging systems, energy supply, and digital management platforms, a disturbance in one area can quickly propagate to others. For example, **flooding** can damage depot infrastructure, disable charging systems, and strand buses, which in turn disrupts services and affects commuter mobility. Similarly, **cyclone-induced power outages** can halt charging operations, leading to prolonged fleet downtime, revenue loss, and increased public dissatisfaction. Or a **cyber-attack** on the charging management system could overcharge batteries, leading to **thermal runaway, fire spread in depots**, and **extended service disruption**.

The illustration below depicts how any single disruptive event can cascade through interconnected components within an EBES and amplifying its impact.

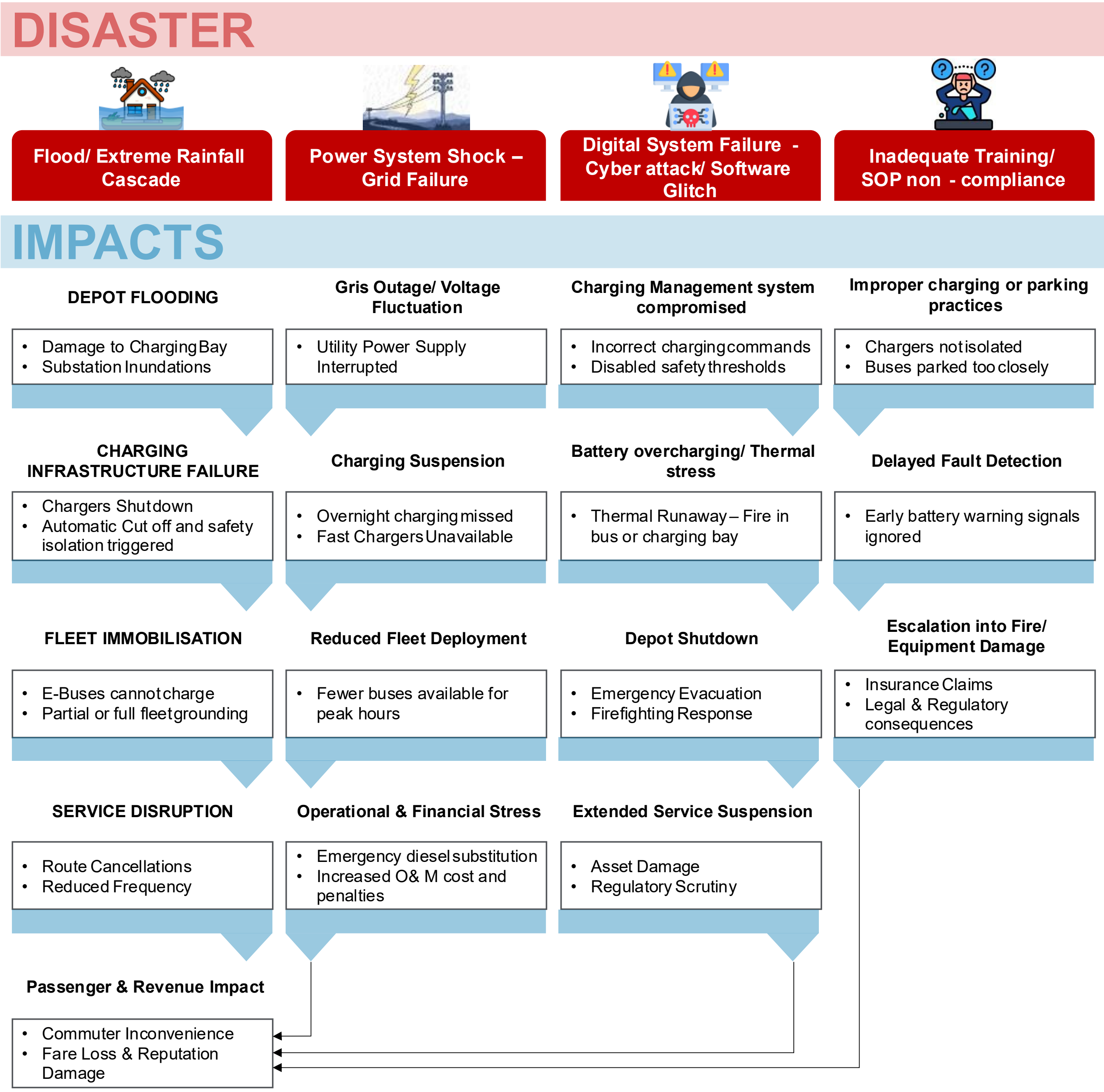



*Exhibit 19 Domino Effect - Cascading Failure*

Understanding these interdependencies is important. This document applies event chain mapping to identify such risk pathways and guide pre-, during-, and post-disaster interventions that contain and break domino effects.

## 3.2. Mapping the Risk Horizon

In EBES, resilience begins with a clear understanding of the risks that could hamper operations. The exhibit below charts the **hazard landscape** - from **natural threats**, technological **risks** and **human-induced challenges**. Mapping these hazards against **key e-bus components** - fleet, depots, charging infrastructure, and the operating environment brings out how each risk interacts, overlaps, and, at times, cascades into larger disruptions.

| HAZARD TYPE | FLEET | DEPOT | CHARGING INFRASTRUCTURE | OPERATING ENVIRONMENT |
|---|---|---|---|---|
| **NATURAL HAZARDS**<br>Floods, Cyclones, Heatwaves, Earthquake, Landslide | Water damage Halted movement<br>Structural stress Trapped buses<br>Stability threats Limited mobility<br>Battery risk Thermal issues | Inundation Equipment failure<br>Collapse risk Structural damage<br>Roof damage Access blocked<br>Material wear Ventilation issues | Water exposure Short circuits<br>Unstable zones Severed connections<br>Vulnerable stations Power disruptions<br>Charger stress Charging slowdown | Route disruptions Operational gaps<br>Coordination issues Service delays<br>Staff coordination Extended recovery<br>Scheduling strain Route adjustments |
| **TECHNOLOGICAL HAZARDS**<br>Battery Failure, Grid Instability, Cyber Threat, Technological obsolescence | Battery fires Rapid spread<br>Grid dependency Charging halted | Chain reactions Multiple units<br>No backup power Stranded buses | Thermal management Equipment damage<br>Voltage fluctuations System stress | Protocol gaps Response delays<br>Coordination failure Public mobility impact |
| **HUMAN INDUCED HAZARDS**<br>Traffic Accidents, Protest, Human Negligence | Digital controls Malware<br>Labor unrest Blocked buses<br>Poor training Accidents | Software vulnerabilities Data breaches<br>Infrastructure risk Equipment tampering<br>Maintenance gaps Operational disruptions | Unauthorised access Overloads<br>Vandalism targets Damaged equipment<br>Incorrect procedures Process failures | Protocol gaps Trust impact<br>Political instability Confidence impact<br>Staff negligence Persistent gaps |

*Exhibit 20 Types of Risks Affecting E-Bus Systems*

## 3.3. Risk Assessment Framework - Hazards, Risks and Vulnerability

Considering the variety of hazards that have potential to affect EBES, a diagnostic approach must be followed while building e-bus depots. To facilitate this, a Risk Assessment Framework for Electric Bus Depots is developed. It aims to provide a structured, data-driven approach to identifying and evaluating the risk levels of the e-bus depots. The public bus transport agencies can use this framework to assess the risk level of the e-bus depots to various kinds of hazards.

This framework is developed based on the Bivariate Risk Matrix Method developed by the Asian Development Bank (ADB, 2016), which is used widely for risk assessment in transport sector. The framework was adapted to encompass climate-centric, technological and human-induced hazards. It evaluates risk through three interlinked elements:

- **Hazard Likelihood and Intensity:** Assesses the probability and severity of natural (e.g., floods, cyclones, earthquakes), technological (e.g., battery fires, cyber threats), and human-induced (e.g., accidents, vandalism) hazards.
- **Exposure:** Measures the quantum of assets and operations at risk, including the e-bus fleet, depot infrastructure, charging systems, and operating environment.
- **Vulnerability**: Evaluates the susceptibility of system components to damage, based on factors such as training, safety protocols, infrastructure quality, and institutional preparedness.


*Exhibit 21: Key elements of Risk Assessment Framework*

A structured framework is created to measure hazard levels for various cities along with exposure and vulnerability analysis for e-bus depots. Annexure A contains detailed list of parameters for conducting hazard, exposure and vulnerability analysis.

### Consequence and Risk Scoring

Upon completion of exposure and vulnerability analysis for an e-bus depot, the consequence score is derived from exposure and vulnerability using the formula:

$$Consequence = (0.7 \times Exposure) + (0.3 \times Vulnerability)$$

The consequence formula is based on the standard ADB approach, which provides a structured method for estimating the potential impact of hazards. A higher weightage 70% is assigned to exposure because it represents tangible values at risk such as people, assets, infrastructure, and financial loss.

While the original methodology recommends 70% and 30% weightage for exposure and vulnerability respectively, cities or public bus transport agencies are encouraged to **adjust the weightages** based on their local conditions, risk profiles, and planning priorities for the e-bus depot under evaluation. This flexibility enables customized assessments while maintaining alignment with established international standards. The indicative examples for customising the weightages in consequence formula are illustrated below.

**Depot A – High Physical Exposure but Strong Systems**

- **Scenario:** E-bus depot and operational routes fall in low-lying/ flood prone zones, but transport agency has robust disaster preparedness and climate response protocols.
- **Weights:** Exposure = 70%, Vulnerability = 30%

***City B – Detailed Vulnerability Data Available***

- ***Scenario****: The depot fewer buses. The institutional protocols, ICT integration in its transport systems is in place*
- ***Adjusted Weights****: Exposure = 55%, Vulnerability = 45%*

***City C – Low Hazard, but New E-bus Program***

- ***Scenario****: The city is not highly exposed to natural hazards. It is in the early stages of e-bus deployment, with untested SOPs and limited grid planning.*
- ***Adjusted Weights****: Exposure = 50%, Vulnerability = 50%*

The final risk score is calculated by overlaying the hazard likelihood on the consequence matrix using a 5×5 bivariate risk matrix.

***Risk = Consequence * Hazard***

Risk levels are classified as Very Low, Low, Moderate, High, or Very High as shown in the table below

| Risk scale | Risk Level | Very Low Risk | Low Risk | Moderate Risk | High Risk | Very High Risk |
|---|---|---|---|---|---|---|
| | Risk Scores | 1 to 4 | 5 to 8 | 9 to 12 | 13 to 16 | 17 to 20 |

This framework enables data-driven risk mitigation planning for urban EBES. It is particularly useful for city transit agencies, private operators, disaster management authorities, and urban planners. By applying this methodology, cities can enhance the resilience of public transport services and protect critical infrastructure from future shocks.

A detailed risk assessment of the identified e-bus depot in an Indian city is conducted basis the primary data collection is enclosed in Annexure A for deeper understanding of the Risk Assessment Methodology.

## 3.4. Synthesis of Findings and Transition to Actionable Strategies

The risk landscape and risk assessment framework provide critical insights into the complex interplay between various risks/ hazards and the components of the EBES. The diagnostic process revealed that while certain cities have initiated efforts toward resilience planning, significant gaps remain, particularly in standardised risk assessment methodologies, real-time hazard monitoring, system-wide preparedness protocols, and institutional coordination. Key learnings highlight the need for hazard-specific SOPs, context-sensitive planning tools, stronger inter-agency linkages, integration with national level early warning systems and targeted investments in training and infrastructure upgrades.

Building on these findings, chapter 4 of the study focuses on translating these insights into actionable strategies through the formulation of a Guidance Document and SOPs. These tools will serve as practical resources for state transport undertakings, city transit agencies, and other relevant stakeholders, enabling them to enhance preparedness, streamline emergency response, and embed resilience into future planning and operations of EBES.

# 4. Framework for E-Bus Hazard Resilience Ecosystem

Given the complex and evolving risk landscape surrounding the EBES including hazards related to high-voltage systems, thermal events, climate-induced disruptions, and human induced deficiencies, it becomes imperative to integrate disaster preparedness across all stages.

The Hazard Impact Framework provides a structured approach to identifying, assessing, and managing risks across the EBES. The ten key hazards are grouped into three broad categories such as natural hazards, technological hazards, and human-induced hazards and assessed their potential impacts on four critical components: e-buses, charging infrastructure, depot infrastructure and management, and the operating environment.

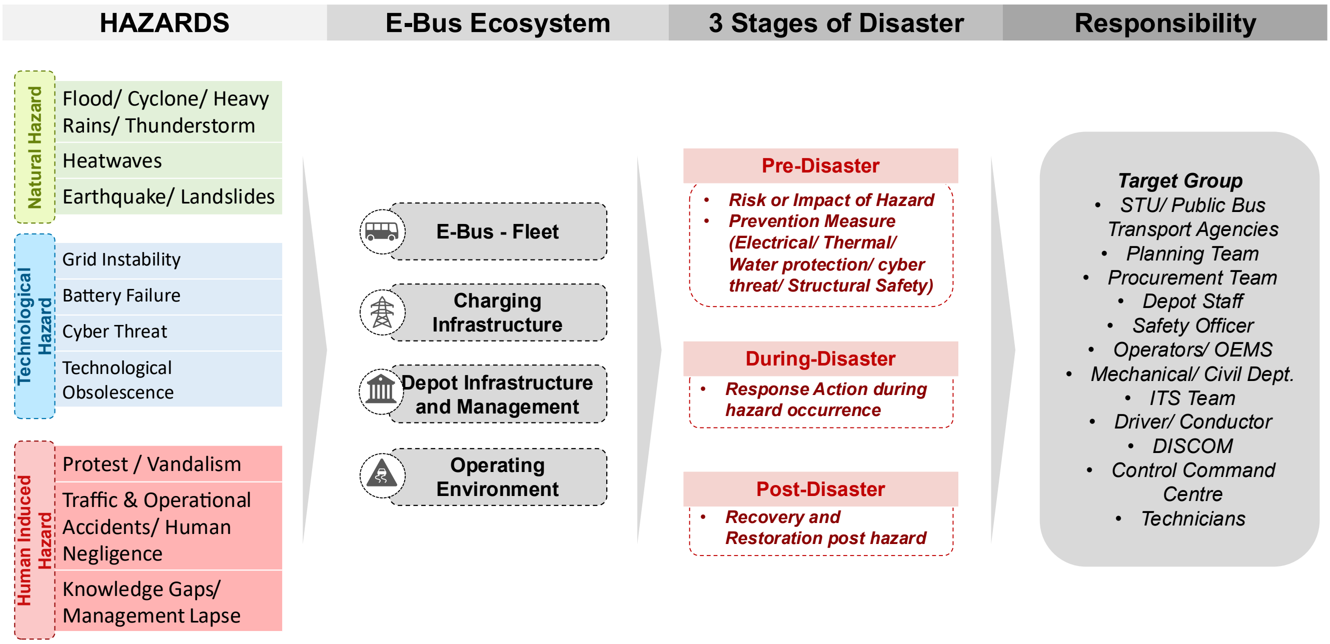



*Exhibit 22 Hazard Impact Framework*

For each hazard, evaluation of the risk or impact level for these components, developed targeted preventive measures to reduce vulnerability, and formulated detailed response protocols and SOPs to be activated during the event. The framework also integrates recovery and restoration strategies to ensure a return to safe and reliable operations. These three stages of disaster management that includes prevention, response, and recovery are further mapped to relevant target audiences at each stage, identifying who is involved in hazard preparedness who is mobilised to maintain or restore operations when a hazard strikes, and who is responsible for long-term recovery and rehabilitation. This ensures a holistic, role-specific, and actionable plan for resilience across the entire EBES.

**<u>Impact Mapping of Hazards on E-bus components</u>**

Each hazard can trigger a chain of events that disrupt operations, damage assets, or endanger lives. Event chain mapping helps identify how a hazard initiates cascading impacts across different components. The following table summarises key hazard-impact pathways to support proactive disaster planning and system resilience.

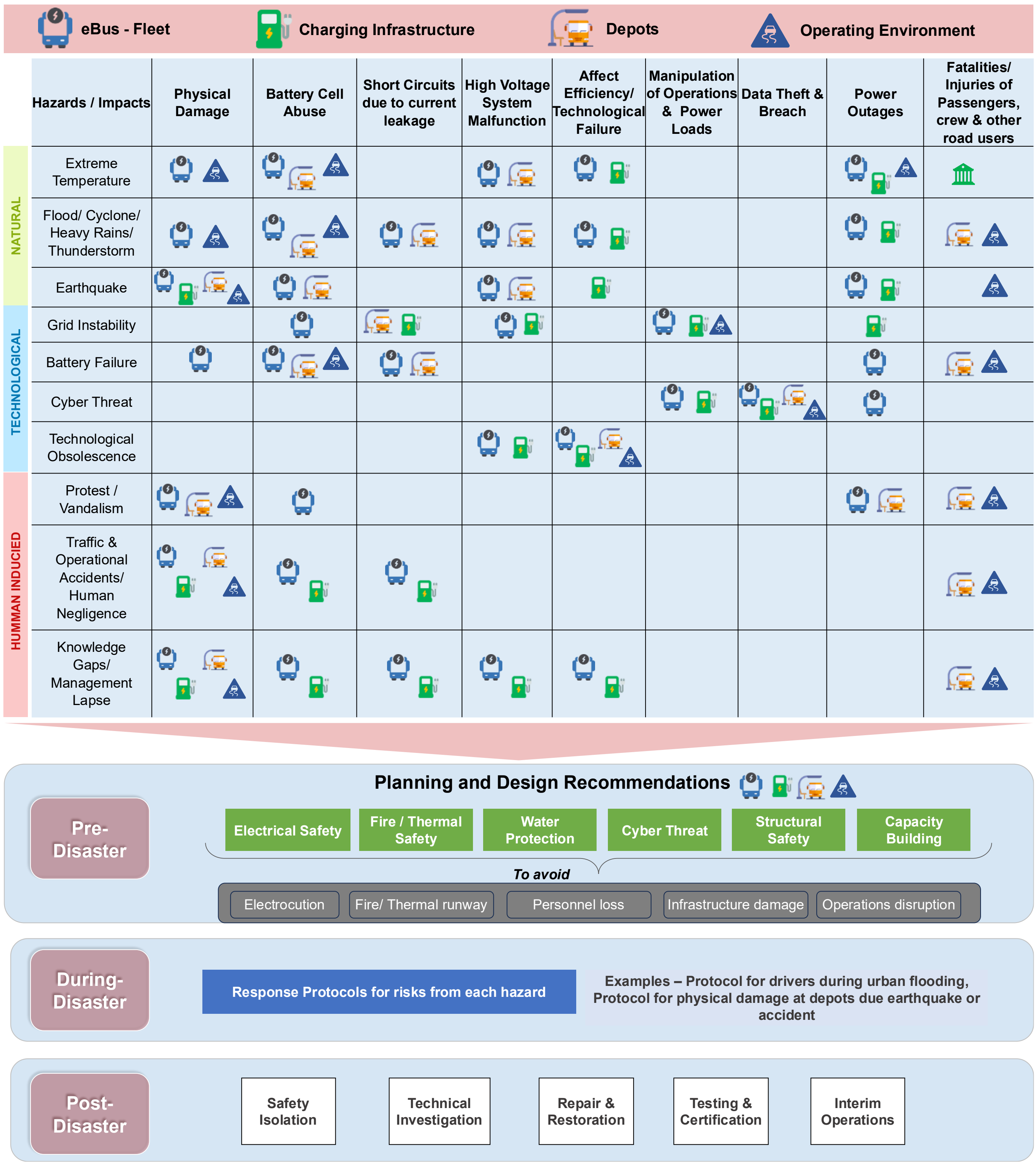



*Exhibit 23 Impact Mapping of Hazards on E-Bus Components*

Based on the understanding of impact of each hazard, recommendations are provided for pre-disaster, during disaster and post disaster stages.

The **pre-disaster phase** emphasises proactive preparedness through **planning, design, and compliance with safety standards**. Key measures include hazard and risk assessments, disaster-resilient features in infrastructure (e.g., elevated charging stations, fire-rated enclosures), and establishing emergency protocols. Building workforce capacity through targeted training and skill development along with public outreach and awareness is essential to ensure readiness. Critical system like ITMS, Early Warning System (EWS), fleet management platforms must also have robust backup and fail-safe mechanisms to maintain continuity during disruptions.

The **during-disaster phase** focuses on **hazard response and emergency operations**. It includes implementing shutdown procedures, isolating affected electrical systems or depots, deploying emergency response teams, safeguarding lives and assets, and coordinating with local authorities to manage traffic, evacuate areas if needed, and communicate with passengers and staff.

The **post-disaster phase** emphasizes **damage assessment, safe restoration of service, and strengthening system resilience**. It includes thorough inspection of all assets (fleet, chargers & depot infrastructure) to identify failures followed by controlled resumption of operations. SOPs should be reviewed and updated based on lessons learned, with necessary upgrades to infrastructure and processes to prevent recurrence. This phase must also include systematic logging of incidents, detailed investigations, comprehensive reports, documentation of learnings, and action-taken records, all stored in an accessible repository to ensure transparency and continuous improvement.

These protocols address the full spectrum of outcomes associated with key risk scenarios such as fire outbreaks, flooding and other natural disasters, seismic impacts, and power disruptions by integrating preventive design considerations, real-time emergency response procedures, and systematic recovery planning tailored for electric fleet operations, depot infrastructure, charging ecosystems and operating environment.

# 5. Hazard Specific Strategies for Pre-, During & Post Disaster Recovery

This chapter presents a structured hazard and component-wise risk and impact mapping for the EBES, covering fleet, depots, charging infrastructure, and operating environment. For each identified hazard, risks are mapped against vulnerable components, followed by clearly defined pre-disaster, during-disaster, and post-disaster strategies. The framework is organised in an event-chain or decision-tree format to enable step-by-step situational assessment and response, which will later be developed into an interactive, user-friendly format. Responsibility mapping is integrated to assign clear accountabilities for each stage of disaster management. Detailed pre-, during-, and post-disaster measures are elaborated in the subsequent module B for operational clarity.

For every identified hazard across the different e-bus components, the recommendations are structured within the following framework.

01 **Hazard Categories**
Ten key hazards, grouped into three broad categories viz. natural disasters, technological hazards, and human-induced hazards.

02 **Key Risks to E-Bus Eco-System Components**
Climate and disaster risk mapping covering hazards, exposure and vulnerabilities of the system

03 **Pre-disaster (Preparedness Measures)**
Pre-disaster planning and design, risk mitigation, training, EWS for better preparedness, infrastructure reinforcement, and operational adjustments based on best practices and regulations.

04 **During Disaster (Response Protocols)**
Step-by-step actions during hazard events, with clear stakeholder roles and responsibilities.

05 **Post-Disaster (Recovery)**
Recovery and restoration efforts following build back principle, inspections, phased return to service, and lessons learned.

06 **Responsibility Mapping**
Key personnel responsible for recommended activities (pre, during and post).

*Exhibit 24 Hazard specific framework across all the different e-bus components with targeted recommendations*

## 5.1. Floods/ Cyclones/ Heavy Rains/ Thunderstorms

Flood, cyclones, heavy rains and thunderstorm pose multiple and interconnected risks to the EBES affecting fleet, depots, charging infrastructure, and the operating environment simultaneously. Key risks include water ingress into batteries, traction motors and electronic system leading to vehicle damage and safety hazards. Substation and chargers are vulnerable to flooding and power outages, disrupting charging operations. Depots face risks such as inundation of parking bays, workshop and control room, along with access blockages during extreme weather events. Strong wind can cause structural damage, while flooded or unsafe roads result in service disruption and delays.

This section maps the risk and impact mapping for flood and storm related hazards across all EBES components. It highlights key vulnerabilities and outlines component specific prevention, response, and post-disaster recovery strategies. The accompanying infographics detail component wise risks and resilience measures to protect assets and ensure rapid service restoration.

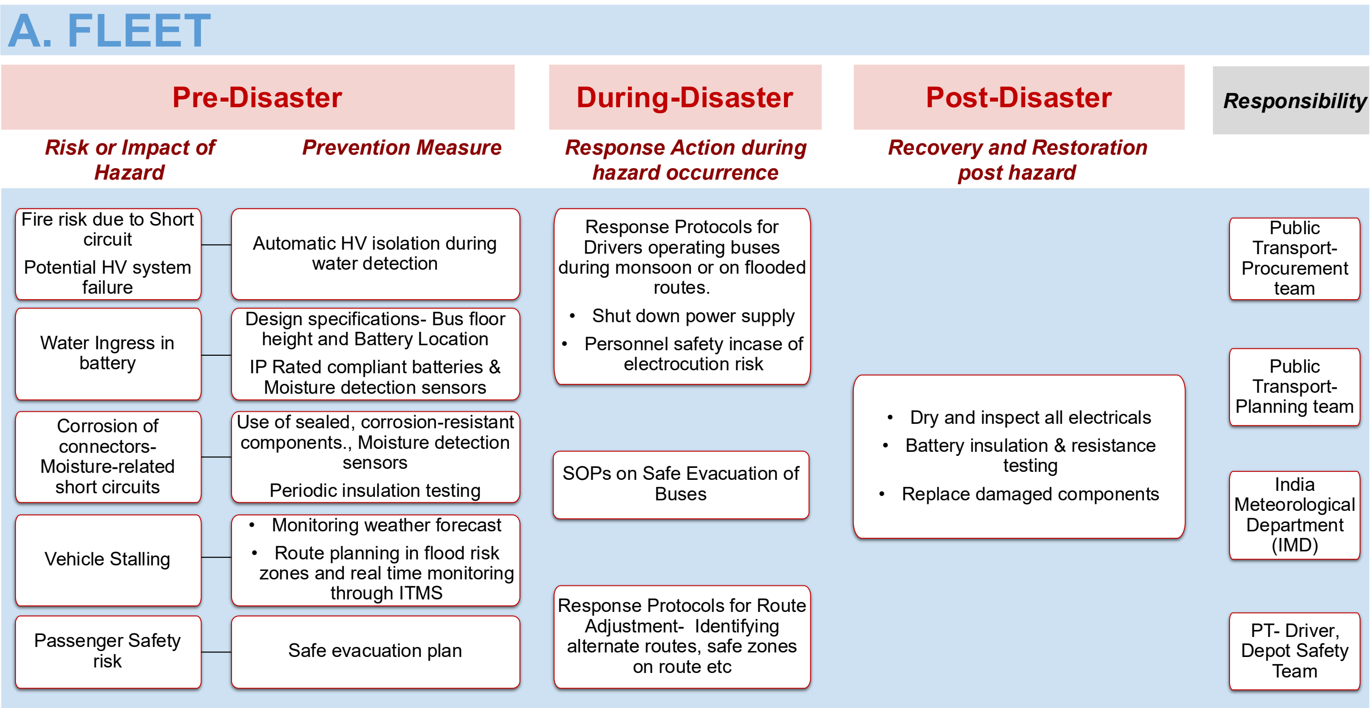



*Exhibit 25 Flood/Cyclone-specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

# B. DEPOT

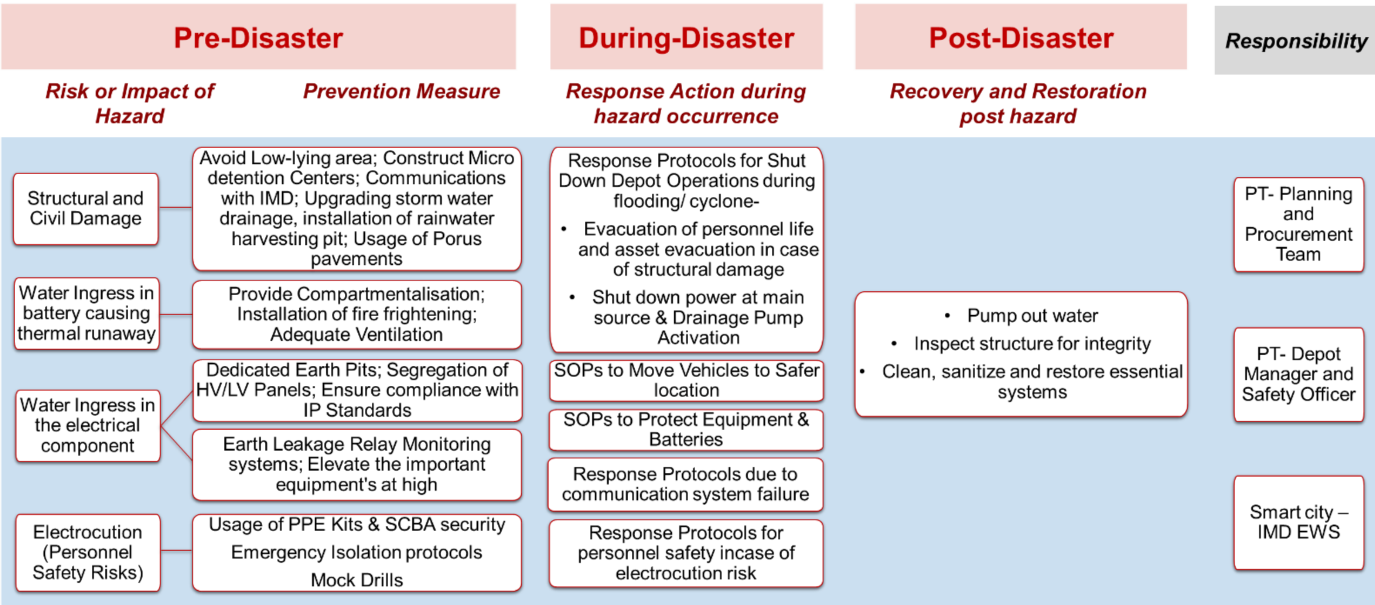



*Exhibit 26 Flood/Cyclone-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

# C. CHARGING INFRASTRUCTURE

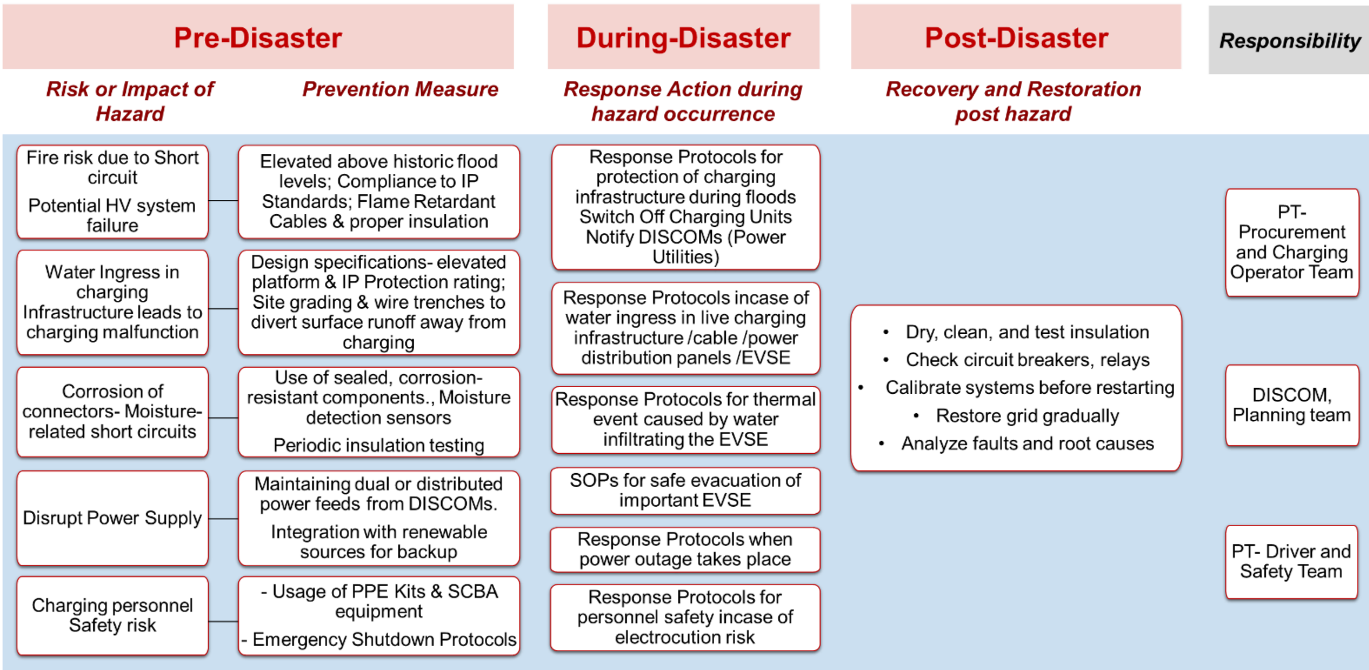



*Exhibit 27 Flood/Cyclone-specific Charging Infra -level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

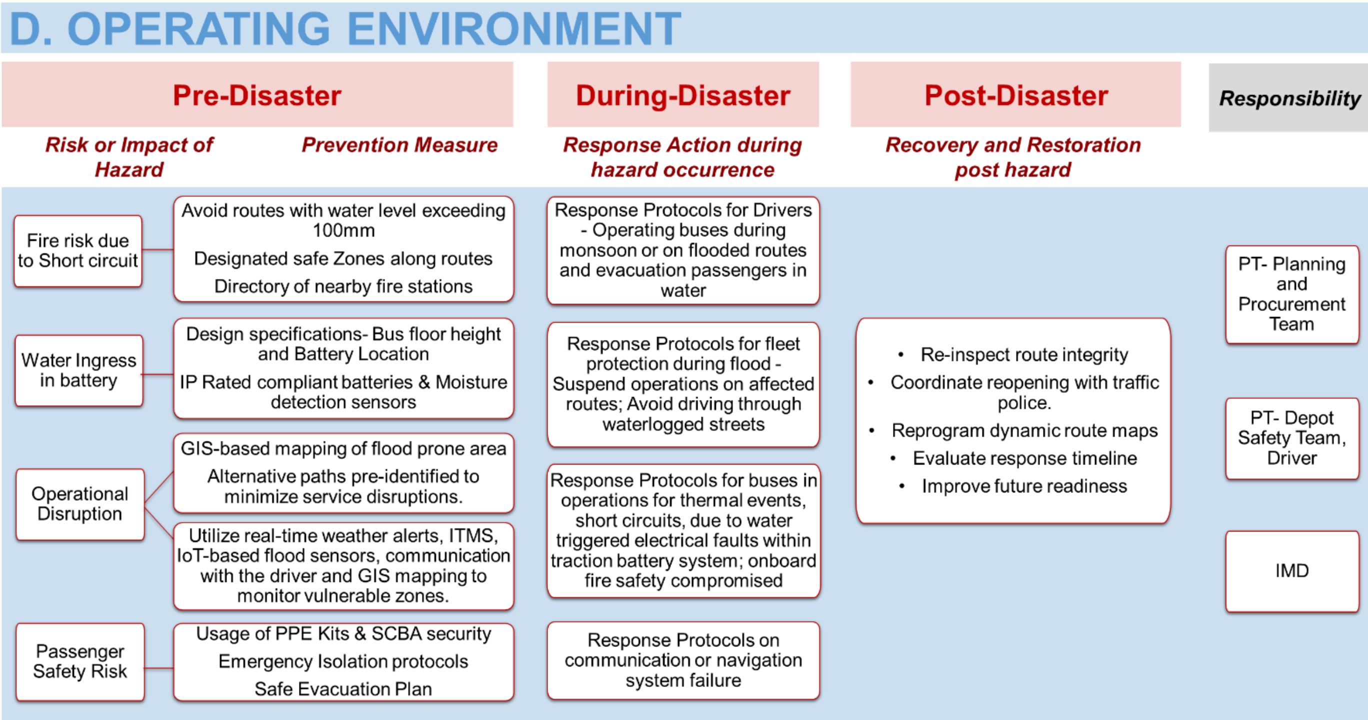



*Exhibit 28 Flood/Cyclone-specific Operating Environment-level Strategy for Pre, During & Post Disaster Recovery*

## 5.2. Heatwaves

Heatwaves poses significant and escalating risks across all the component EBES. Elevated temperature increases the likelihood of battery overheating, thermal runaway, reduced charging efficiency, electronic system failures, higher HVAC loads and heighten safety risks for passengers and staff. Prolonged heat exposure also contributes to driver fatigue, health stress and operational inefficiencies.

The section addresses these through preventive measures including heat-resistant design, enhanced ventilation and shading, real time thermal and BMS monitoring systems, adaptive charging schedules, load management, staff safety protocols and passenger protection measures. Post-event recovery actions involve isolation of affected bus, comprehensive component inspections, system recalibration, and thermal resilience upgrades to ensure the continued safety and reliability of operations. The accompanying infographics detail component-specific risks and corresponding strategies to protect assets and people, maintain operational continuity and enable rapid recovery following extreme heat events.

## A. FLEET

### Pre-Disaster

| Risk or Impact of Hazard | Prevention Measure |
|---|---|
| Battery Overheating | Use heat-resilient batteries. Real-time battery thermal monitoring. Upgrade/verify Battery Management System (BMS) & Add auxiliary cooling or fans |
| Reduced Range | Adjust duty cycles to cooler hours. Monitor real-time SoC (State of Charge) data & Reconfigure routes for shorter round trips |
| Interior Cabin Overheat | Service HVAC systems pre-summer. Use cabin insulation films or blind and Install roof insulation sheets or reflective paints |
| Fire or Smoke Risk | Install thermal sensors & fire alarms & Equip buses with Class D extinguishers. Train drivers on early signs of fire or smoke |
| Component Wear & Tear | Conduct summer-ready fleet health checks & Replace vulnerable parts in advance. Store buses in shaded or ventilated depots |

### During-Disaster

**Response Action during hazard occurrence**

Response plan for bus operations during heatwaves-

- Activate fleet heatwave SOPs
- Operate in early morning/evening hours
- Monitor BMS battery temp - Pre-cool cabins before dispatch

Response plan for handling overheated buses

### Post-Disaster

**Recovery and Restoration post hazard**

- Conduct post-event battery health diagnostics
- Review AC performance logs
- Adjust service plans if degradation occurred
- Update SOPs based on incident reports

### Responsibility

- PT- Planning Team/ Control Room /
- Operator / Service Contractor
- PT- Depot Manager, Driver
- Fire Department

*Exhibit 29 Heatwave-Specific Fleet-Level Strategy for Pre-Disaster, During Disaster and Post Disaster Recovery*

## B. DEPOT

### Pre-Disaster

| Risk or Impact of Hazard | Prevention Measure |
|---|---|
| Thermal Damage to Idle Buses | Shade structures for parking bays. Use heat-reflective paint or materials. Rotate parked fleet; green facade, cool roofs, plantation and transplantation within depots premises |
| Fire Risk from Charging Areas | Isolate charging zones with heat insulation. Implement remote thermal monitoring systems for bus-charger interactions |
| Heat Stress on Staff | Provide shaded rest zones, hydration stations, and breaks- Install industrial fans or evaporative coolers in work sheds |

### During-Disaster

**Response Action during hazard occurrence**

SOPs for Depot operations during heatwaves/ extreme temperatures

- Limit non-essential outdoor tasks
- Ensure water/fans for staff
- Park buses in shade
- Keep firefighting equipment ready
- Monitor indoor temps

### Post-Disaster

**Recovery and Restoration post hazard**

- Assess structural heat impacts (roofing, equipment)
- Log ventilation or power failures
- Refresh fire and heat safety training
- Update depot emergency readiness plans

### Responsibility

- PT- Procurement Team
- PT- Depot Manager, Driver
- Fire Department

*Exhibit 30 Heatwave-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## C. CHARGING INFRASTRUCTURE

### Pre-Disaster

| Risk or Impact of Hazard | Prevention Measure |
|---|---|
| Charger Overheating | Install roof canopies/shade covers. Use heat-resistant housing/enclosures. Integrate active/passive ventilation systems |
| Reduced Charging Efficiency | Schedule charging at night/early morning. Use temperature-tolerant charger models |
| Thermal Damage to Components | Regular summer maintenance of switchgear and cables. Thermal insulation of charging cabinets |
| Fire/Short Circuit Risk | Use flame-retardant cables/connectors. Conduct regular cable stress tests. Ensure availability of fire suppression systems at charging points |
| Exacerbating grid load during peak period may result in power outage | Coordinate charging schedules with discom. Install energy storage or backup supply systems |

### During-Disaster

**Response Action during hazard occurrence**

Response plan for charging infrastructure operations during heatwaves

- Postpone charging during 12–5 pm
- Use shaded/ventilated charging zones
- Monitor charger heat levels - Disable fast charging if needed
- Keep technical crew on standby

### Post-Disaster

**Recovery and Restoration post hazard**

- Conduct full thermal inspection of chargers and panels
- Recalibrate charging schedules
- Replace or repair heat-damaged components
- Log incident data and update maintenance plans

### Responsibility

- PT- Procurement team, Planning Department
- DISCOM
- OEMs, Charging Operators, Depot Manager
- Fire Department

*Exhibit 31 Heatwave-specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

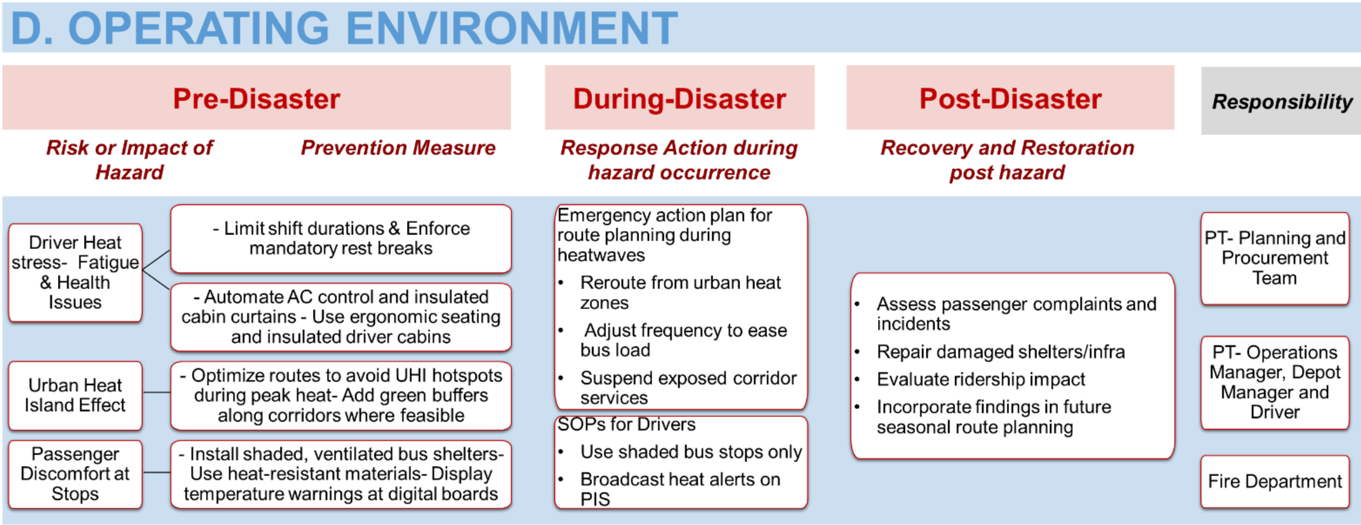



*Exhibit 32 Heatwave-specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.3. Earthquake / Landslides

Earthquake and landslide pose high-impact risks to the EBES, affecting the fleet, depots, charging infrastructure, and operating environment. These hazards can cause structural damage to depots, charging stations, damage to parked buses, power and communication outages, road failures and disruption to passenger infrastructure, severely compromising safety and service continuity.

Fleet assets are exposed to physical damage and fire risks due to seismic shocks; depots face threats to structural integrity, human safety, and battery-related fire hazards; charging infrastructure is vulnerable to equipment failure, grounding issues, and loss of smart charging and communication systems; and the operating environment is affected by landslides, damaged roadways, collapsed shelters, and disrupted energy and communication networks.

Preventive measures focus on seismic-resilient design and secure anchoring of critical assets. During events, response protocols prioritise rapid fleet evacuation, route diversion, and effective emergency communication. Post-disaster actions emphasise systematic damage assessment and phased service restoration to ensure safety and operational continuity. The accompanying infographics summarise component-specific risks and resilience measures to protect lives and assets and support safe recovery of services.

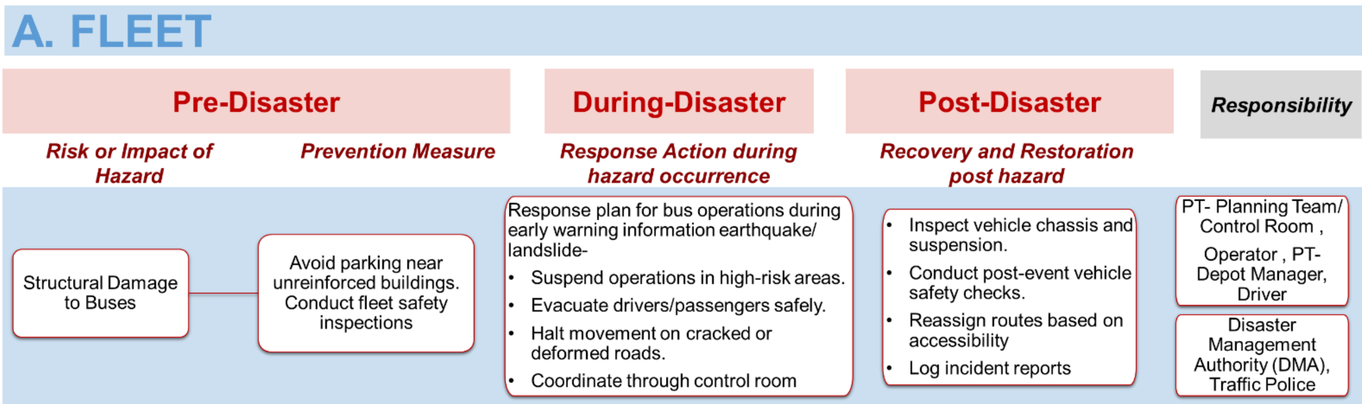



*Exhibit 33 Earthquake/ Landslide-specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## B. DEPOT

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| **Building Collapse** - risking human and asset safety. | Undertake seismic retrofitting. Secure equipment. Create evacuation maps. Conduct quarterly safety drills.<br>Improved drainage, protection with retaining walls with green facia. | SOPs for Depot during earthquake or landslides:<br>• Evacuate all non-essential personnel.<br>• Shut off power and gas lines.<br>• Activate depot emergency response plan<br>• Ensure communication lines remain open | • Conduct structural and utility damage assessment.<br>• Reopen only after safety clearance.<br>• Repair cracked surfaces, roofs.<br>• Train staff on response improvements | PT- Depot Manager, Depot staff |
| **Battery Fire Risk** - Seismic shocks leading to battery spills or internal damage triggering fires. | Use fire-proof battery cabinets.<br>Secure battery storage areas<br>Install thermal sensors and early warning systems. | | | Emergency Team (ULB/ disaster authority) |

*Exhibit 34 Earthquake/Landslide-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## C. CHARGING INFRASTRUCTURE

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Charger Structural Failure | Install chargers with seismic anchoring and retaining wall; assess soil and slope stability; install protective barriers and improve the drainage | SOPs for Depot during earthquake or landslides:<br>• Immediately cut off power to chargers<br>• Disable fast-charging.<br>• Inspect visible cracks or structural movement.<br>• Alert utility in case of grid instability | • Structural assessment of charging points<br>• Repair/replace damaged chargers<br>• Restore power supply with safeguards<br>• Update risk zone maps and SOPs | PT- Depot Manager, Charging Operators, Operator |
| Electrical Hazards- Power surges or grid faults | Install automatic power shut-off systems; enforce grounding and lightning protection standards; train staff on electrical emergencies. | | | ULBs, DISCOM, Fire Department |

*Exhibit 35 Earthquake/Landslide-specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery.*

## D. OPERATING ENVIRONMENT

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Landslide-Prone Corridors | Pre-identify alternate routes using GIS. Share route plans with disaster management teams.<br>Coordinate with SDMA/ IMD for early warnings. | Response plan to re-routing of buses or suspending operations. | • Assess road damage and slope stability.<br>• Coordinate with city for route restoration.<br>• Reinforce slopes/barriers where needed.<br>• Update hazard maps | PT- Planning Team/ Control Room, Depot Manager, Driver, Operator |
| Collapse of Passenger Infra - Bus shelters and stops | Retrofit key passenger infrastructure; conduct visual inspections; use lighter, flexible shelter designs that perform better in quakes. | SOPs for emergency public messaging updating passengers | | Disaster Management Authority (DMA), Traffic Police |

*Exhibit 36 Earthquake/Landslide-specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.4. Grid Instability

Grid instability poses systematic risks across the EBES components. Power fluctuations and outages can disrupt charging operations, degrade battery health, trigger electrical faults and delays service schedules. Fleet operations are vulnerable to voltage instability, leading to risk of battery degradation, fire risks and vehicle stalling. Depots face breaker tripping, short circuits, and operational shutdowns, while charging infrastructure is exposed to equipment malfunction, data and SCADA disruptions, and asset damage. In the operating environment, grid instability results in service delays, passenger inconvenience, and safety risks due to insufficient charge buffers.

The risk and impact mapping identifies key vulnerabilities and defines resilience measures across the pre, during and post-disaster phases. Preventive actions such as installing surge protection devices, relay breakers, on-site renewable energy with battery storage, and smart charging systems. During disruptions, response measures focus on prioritising critical fleet charging and activating backup power. Post event strategies emphasise coordination with DISCOM and system diagnostics to restore operations. The accompanying infographics present component-specific risks and resilience strategies to safeguard asset, ensure operational continuity, and protect passenger safety during grid instability events.

## A. FLEET

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Battery Cell abuse leading to Bus fire/ thermal runaway | Installation of Battery Management System, configure for automatic cut off for over/undervoltage fluctuations | Response Protocols for fleet On unsafe voltage/ frequency is detected while charging | • Check BMS logs for fault/error codes.<br>• Perform BMS diagnostics for any bus charging during instability<br>• Review trip data for anomalies in performance<br>• Resume to normal charging gradually | PT-Procurement team |
| Onboard electronics failure causing short circuits, overloads & over-discharges. | Usage of LiFPo (Lithium-Ion Phosphate) Batteries for better thermal stability<br>Regularly update firmware for power fluctuation protection | Response Protocols for personnel safety and evacuation in case of low battery enroute. | | Charging Operator |
| Stranded Buses – Buses enroute may not be complete trips | Maintain 30-40% SoC reserve at all times | | | Safety & Firefighting Team |

*Exhibit 37 Grid Instability-specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## B. DEPOT

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Safety Hazards from short circuit or tripping of breakers | Compartmentalization with fire protect barrier<br>Train staff on safe isolation procedures.<br>Early communication with DISCOM for advance outage alerts. | SOPs for Depot operations During power outage<br>• Pause all on-essential power use<br>• Prioritize charging for emergency buses<br>• Communicate real-time charging status to operations control. | • Inspect depot electrical distribution & grounding systems.<br>• Resume phased charging to avoid sudden load.<br>• Update preventive SOPs based on incident review. | PT- Procurement Team |
| Inability to Dispatch Buses as per schedule | Maintain staggered charging schedules to avoid overloading.<br>-Keep emergency power backup (BESS/generator). | | | PT- Depot Manager, charging operator |
| | | | | DISCOM |

*Exhibit 38 Grid Instability-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

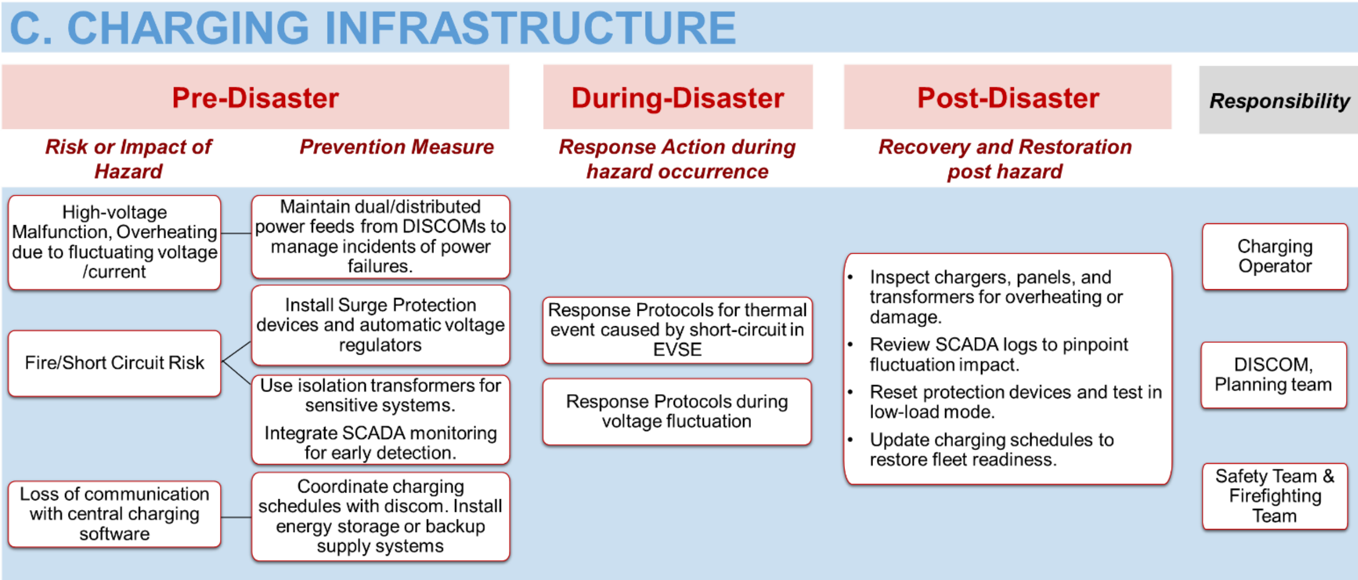



*Exhibit 39 Grid Instability-specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

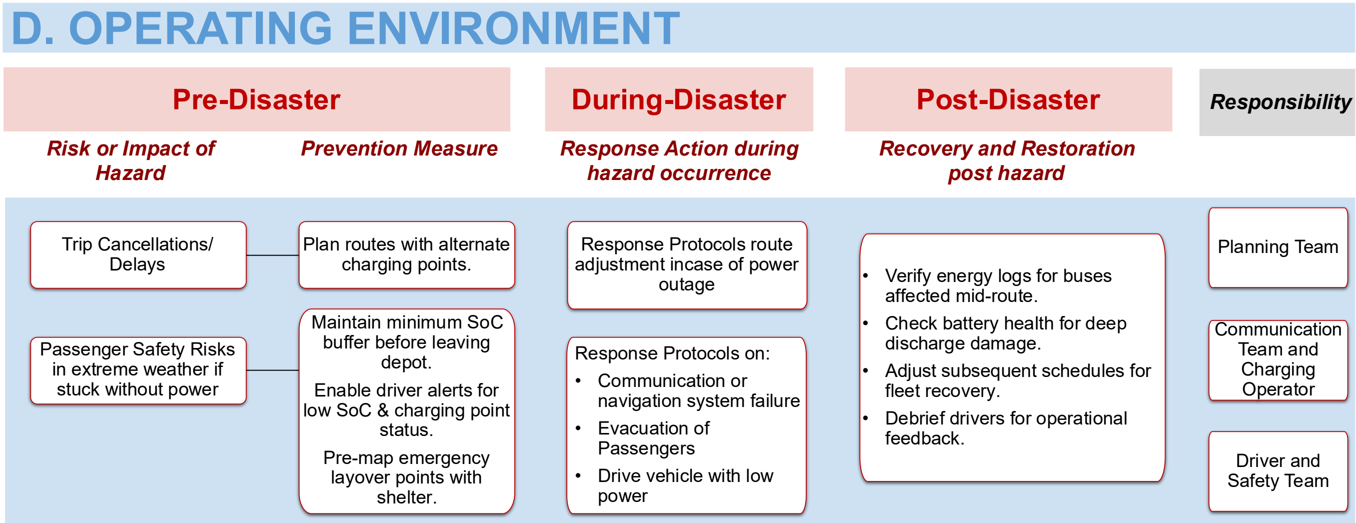



*Exhibit 40 Grid Instability-specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.5. Battery Failure

Battery failure poses one of the highest-severity risks across the entire EBES, with cascading impacts on fleet, depots, charging infrastructure, and the operating environment. Key failure modes include overcharging, over-discharging, overheating, collisions, vibrations, and electrical abuse, which can trigger thermal runaway, fires, system shutdowns, and serious safety risks to passengers, staff, and other road users.

At the fleet level, battery failure can lead to vehicle fires, traction motor overheating, loss of performance, and service disruption. Depots face elevated risks of fire spread, thermal damage to infrastructure, and personnel safety hazards, particularly during parking, charging, or post-collision scenarios. Charging infrastructure is vulnerable to charger overheating, short circuits, and fire incidents that can compromise both assets and charging continuity. In the operating environment, battery failure during operations or after collisions increases the risk of onboard fires, emergency evacuations, traffic disruption, and public safety incidents.

The risk and impact mapping outlines a comprehensive resilience framework across pre-disaster, during-incident, and post-incident phases. Preventive measures include robust Battery

Management Systems (BMS), thermal and smoke detection, fire detection and suppression systems (FDSS), safe charging protocols, resilient vehicle design, depot compartmentalisation, and staff training. Real-time response actions focus on rapid vehicle isolation, emergency evacuation, fire suppression, and coordinated response with fire, police, and disaster management agencies. Post-incident strategies emphasise damage assessment, isolation and safe disposal of affected batteries, infrastructure recovery, and phased restoration of services.

The accompanying infographics present component-specific risks and corresponding resilience measures to protect life and assets, contain incidents, and ensure safe and rapid recovery of e-bus operations following battery failure events.

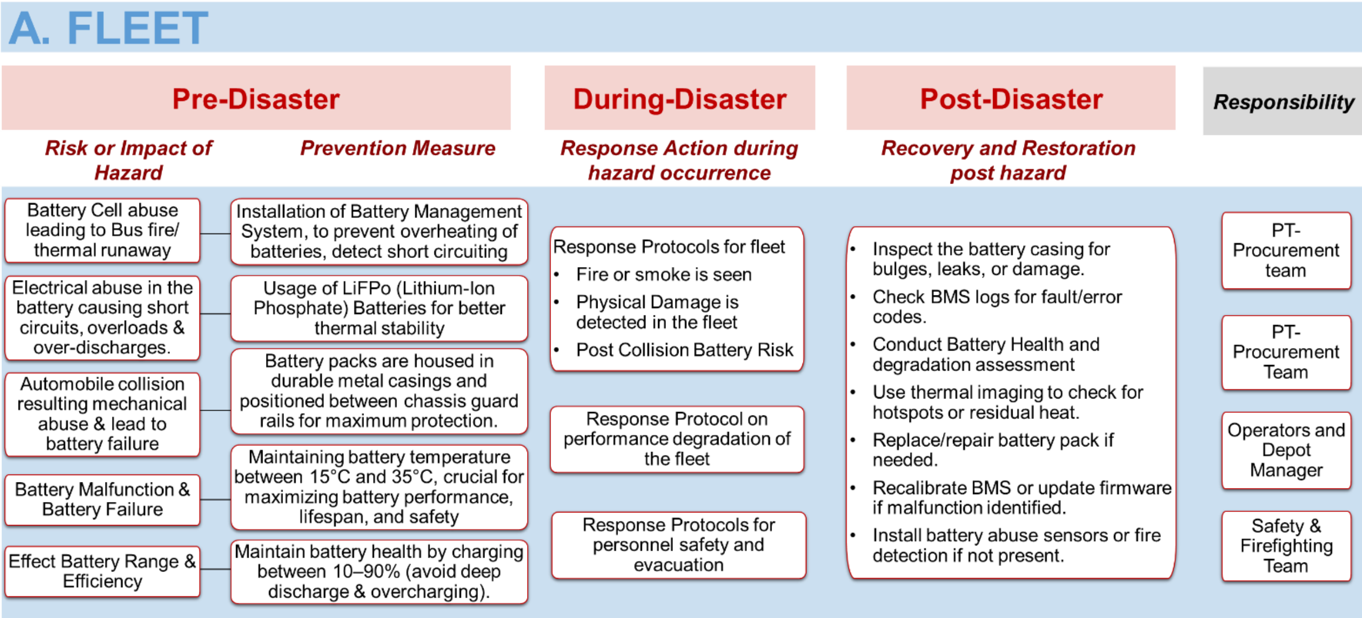



*Exhibit 41 Battery failure -specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

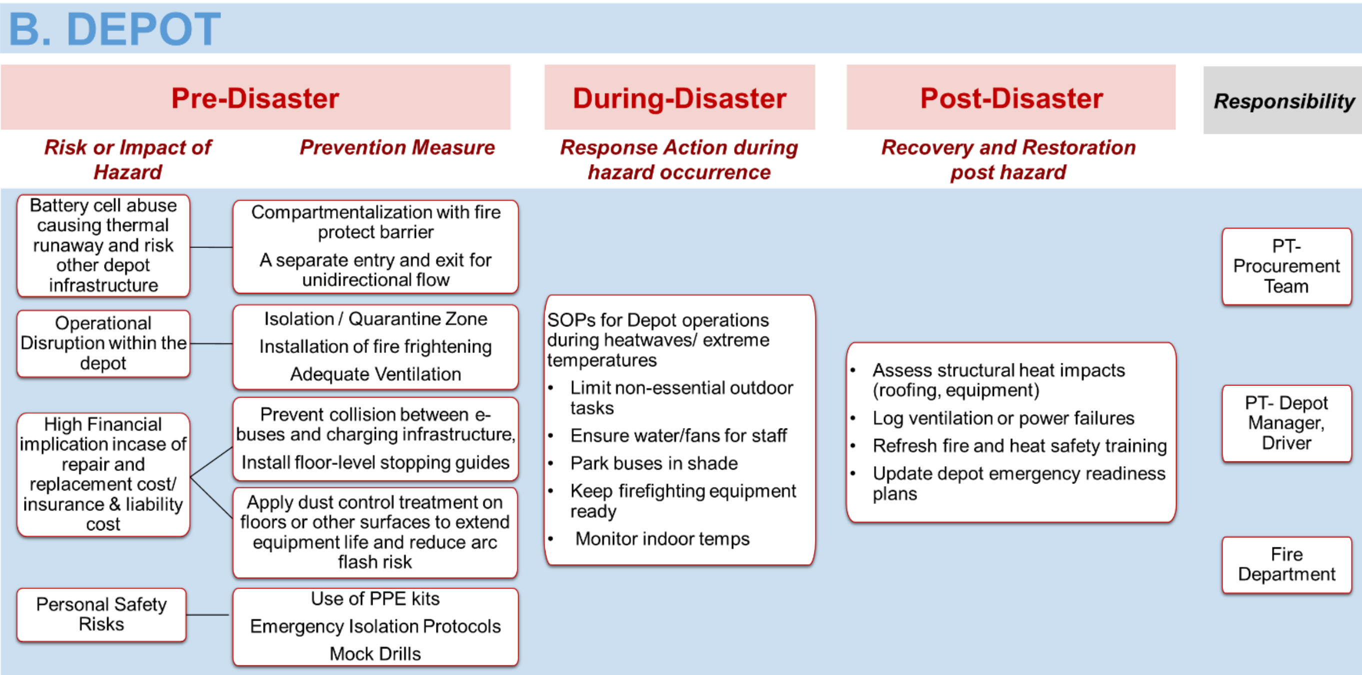



*Exhibit 42 Battery failure -specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

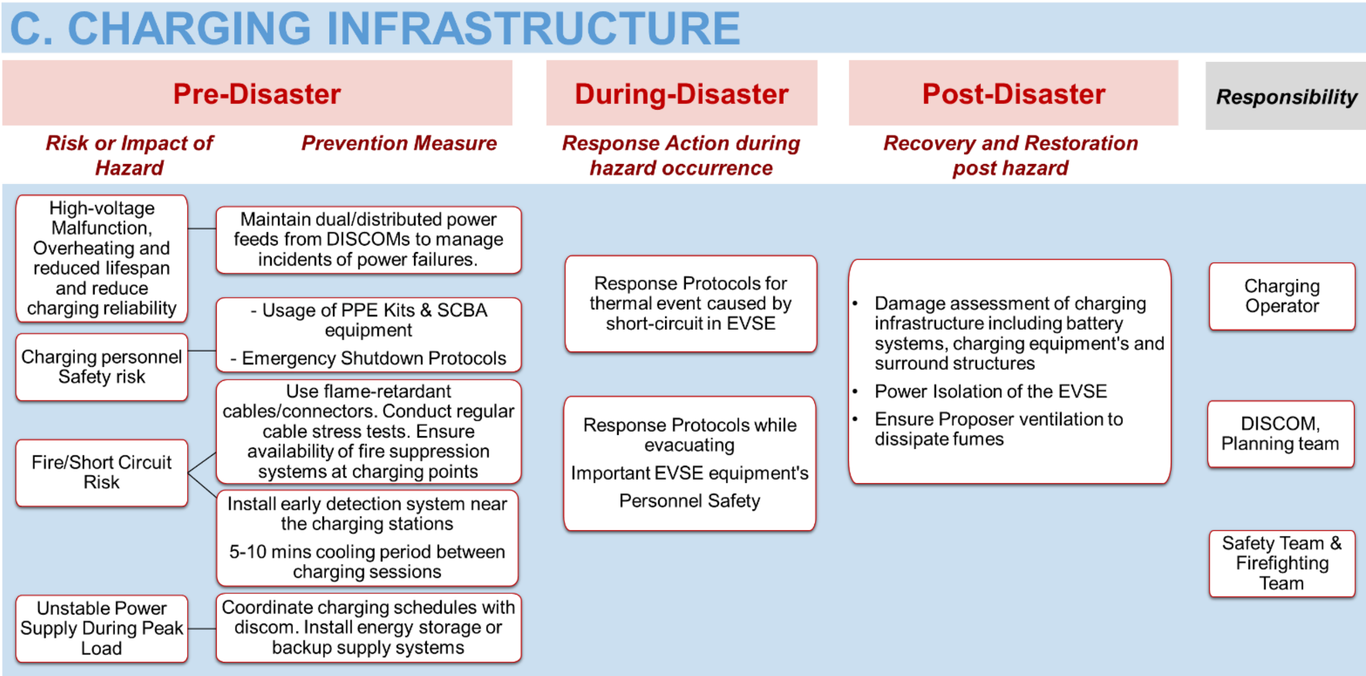



*Exhibit 43 Battery failure -specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

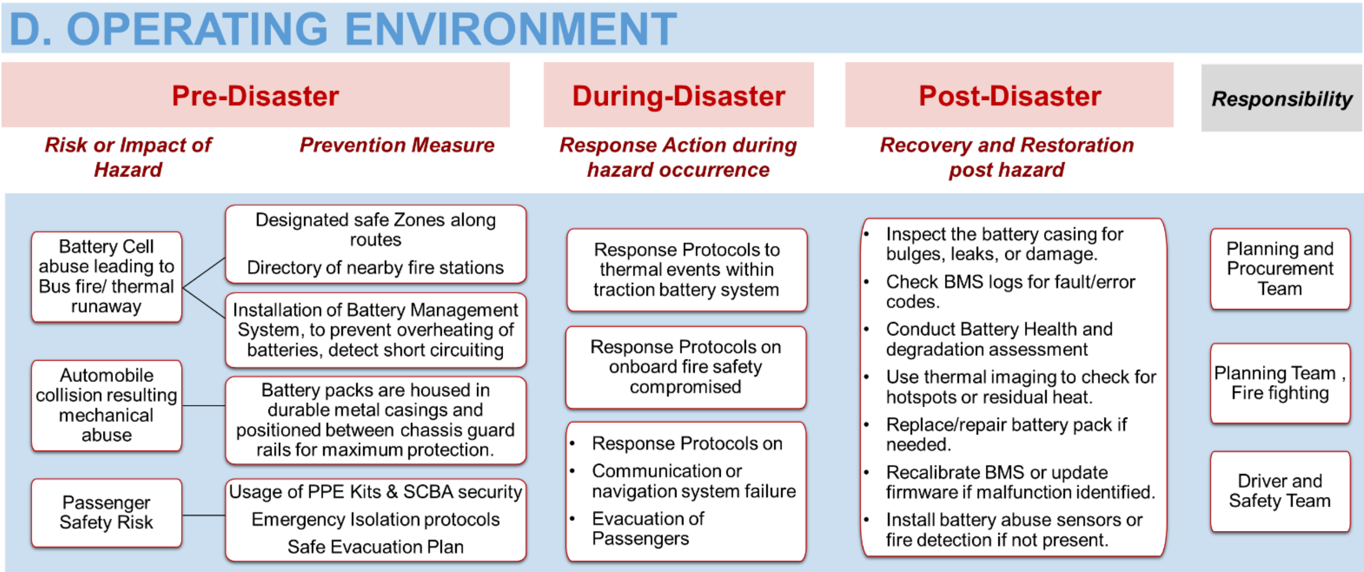



*Exhibit 44 Battery failure -specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.6. Cyber Threat

Cybersecurity risks pose a growing, system-wide threat to the EBES, with cascading impacts across fleet operations, depots, charging infrastructure, and the operating environment. These risks include malicious cyberattacks, unauthorized access, manipulation of vehicle controls, disruption of charging schedules, compromise of passenger data, and interference with depot and control room systems. Such incidents may arise from ransomware, malware, phishing, denial-of-service (DoS) attacks, or manipulation of operational data, potentially leading to service disruptions and safety risks.

Fleet systems are vulnerable to remote intrusion and control manipulation; depots face risks to operational control and sensitive data; charging infrastructure is exposed to disruptions in smart charging, load management, and high-voltage controls; and the operating environment may experience service disruptions and passenger safety impacts due to system outages.

The risk and impact mapping outlines resilience measures across the pre-disaster, during-disaster, and post-disaster phases. Preventive actions include robust firewalls, network segmentation, multi-factor authentication, real-time cyber audits, and staff awareness training. During incidents, protocols focus on rapid system isolation, incident containment, and coordination with cybersecurity teams. Post-incident measures emphasize secure system restoration, forensic assessment, and strengthening of cyber defences. The accompanying infographics present component-specific cyber risks and response strategies to ensure data security, operational continuity, and passenger safety.

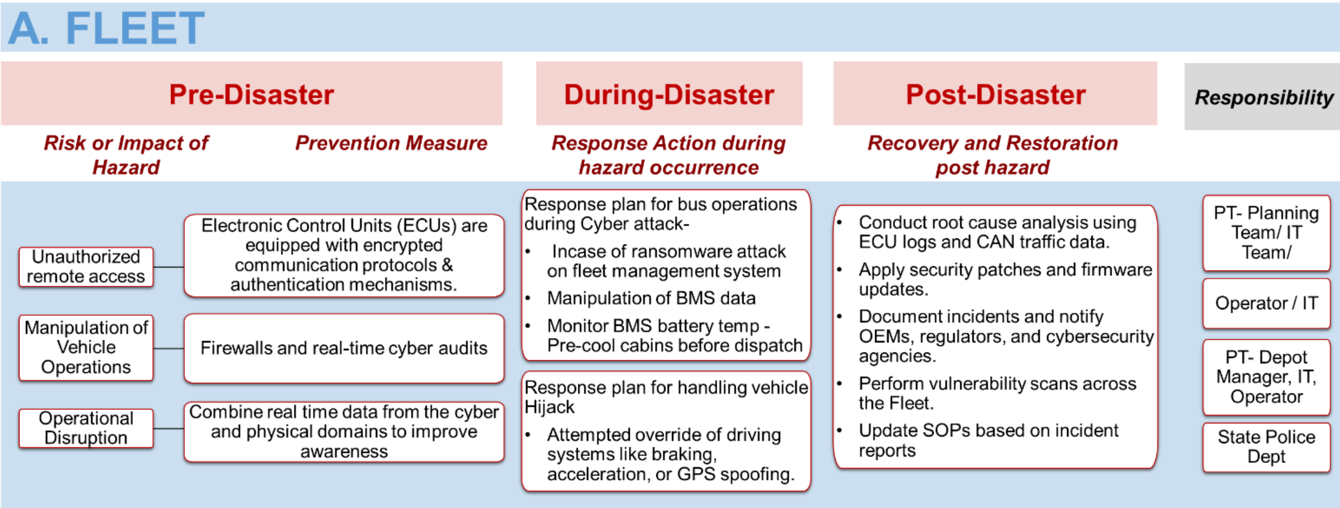



*Exhibit 45 Cyber Threat-specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

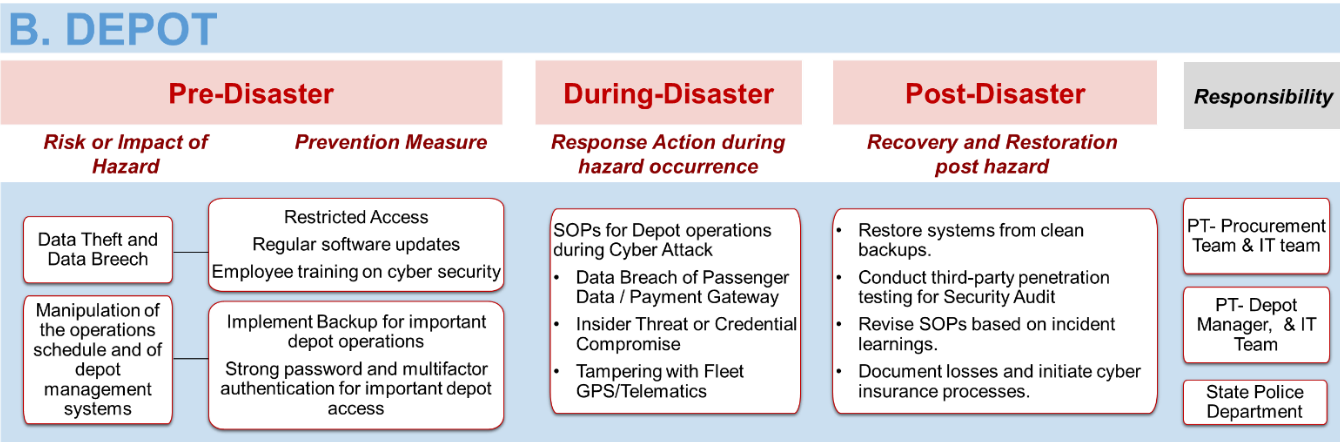



*Exhibit 46 Cyber Threat-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

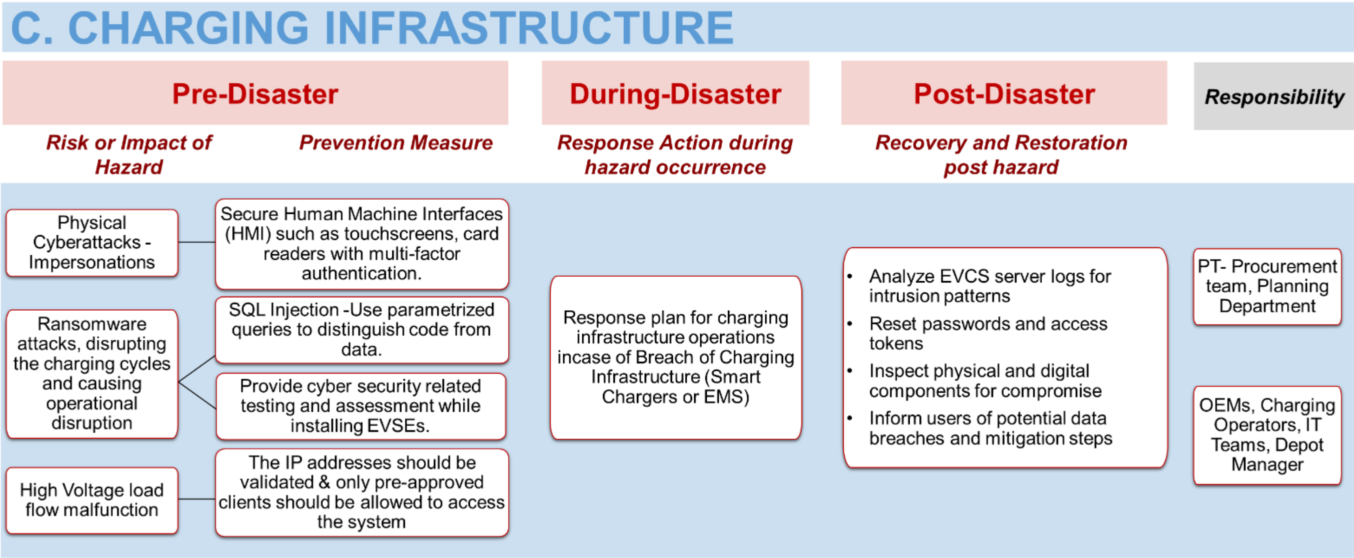



*Exhibit 47 Cyber Threat-specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

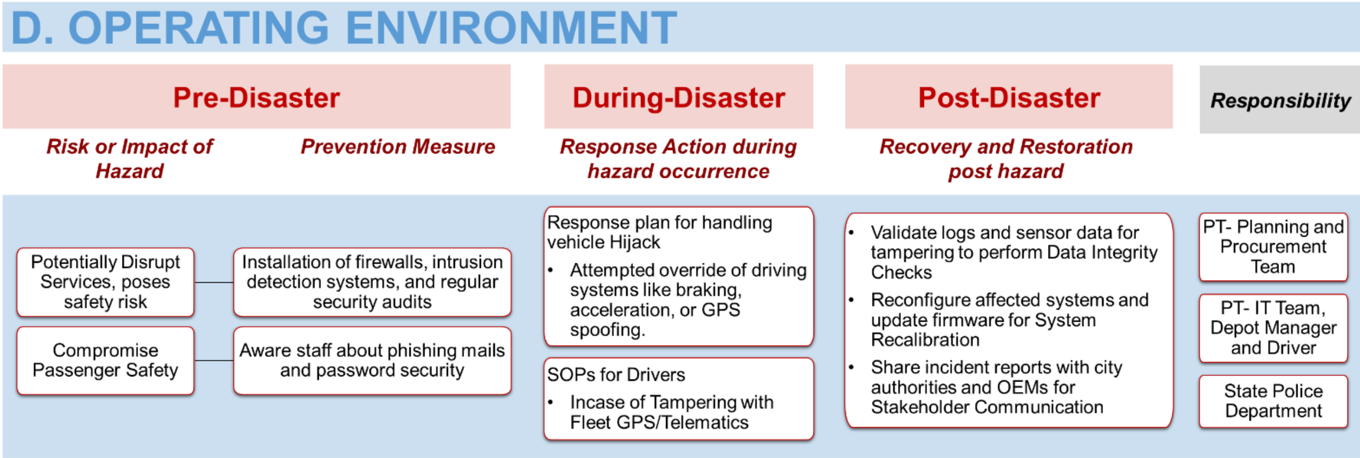



*Exhibit 48 Cyber Threat-specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.7. Technological Obsolescence

Technological obsolescence poses a cross-cutting risk to the EBES, as rapid advancements in battery technologies, charging standards, digital platforms, and fleet management systems can render existing assets outdated or incompatible. In disaster-prone and high-reliability operating contexts, dependence on obsolete hardware, software, or communication protocols can amplify system vulnerabilities, delay recovery, and limit integration with newer resilience-enhancing technologies undermining both operational continuity and financial sustainability.

Fleets face risk from outdated BMS, vehicle control software, and telematics lacking OEM support leading to reduced reliability and inaccurate diagnostics. Depots face operational disruptions when legacy IT and maintenance systems cannot interface with newer vehicle platforms. Charging infrastructure is vulnerable to rapidly evolving standards, where older chargers or firmware may be incompatible with new battery chemistries or communication protocols. At the operating environment level, obsolete ITMS and passenger information systems impair real-time monitoring, routing, and communication during disruptions.

Resilience measures focus on proactive technology lifecycle management, including modular and upgrade-ready system design, regular firmware and software updates, interoperability standards in procurement, vendor-neutral platforms, and planned technology refresh cycles. The accompanying infographics detail component-specific risks and pre-, during-, and post-disaster strategies to manage obsolescence, ensure system compatibility, and maintain reliable and resilient e-bus operations over time.

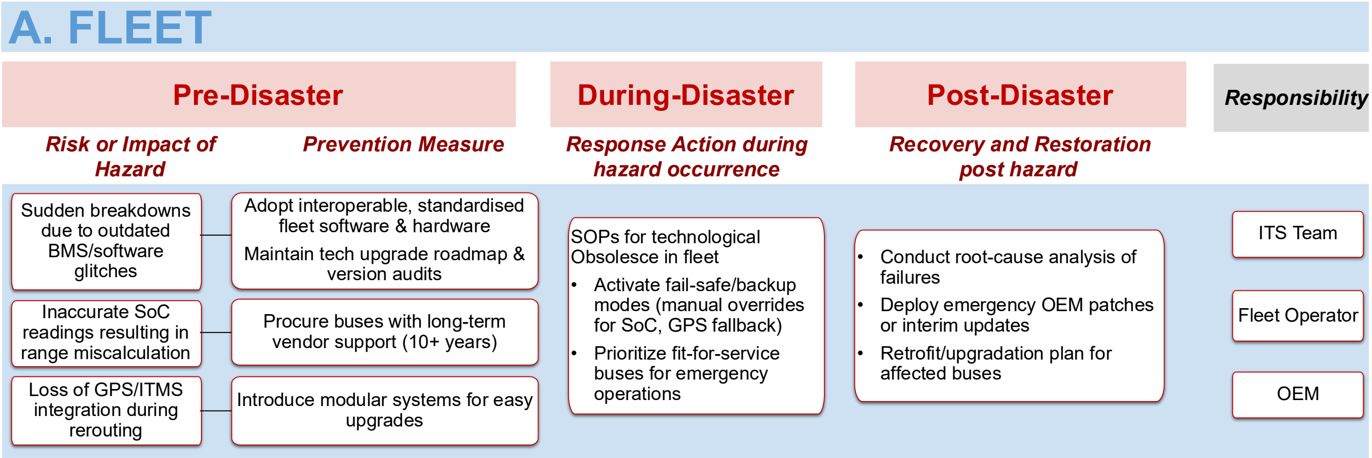



Exhibit 49 Technological Obsolescence-specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery

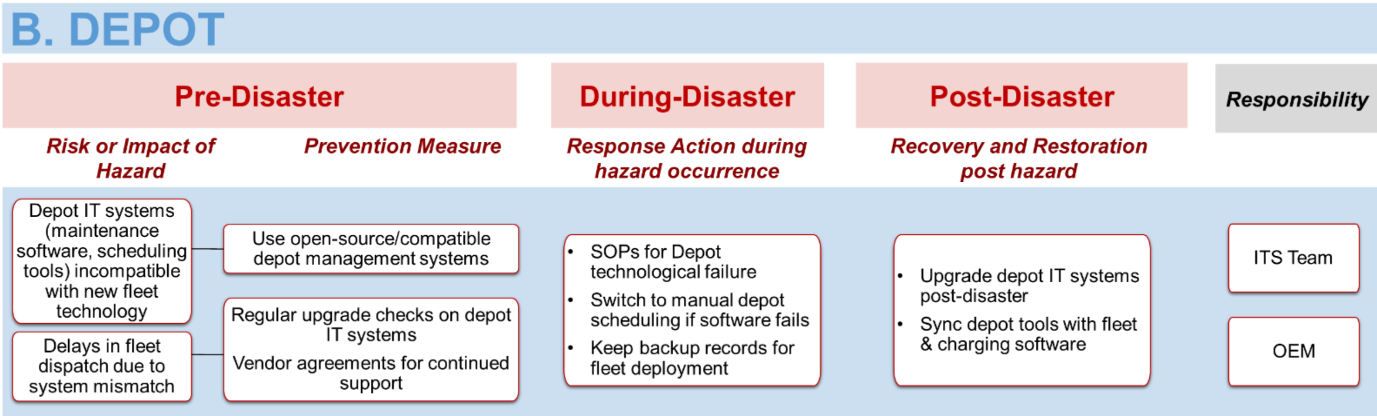



Exhibit 50 Technological Obsolescence-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery

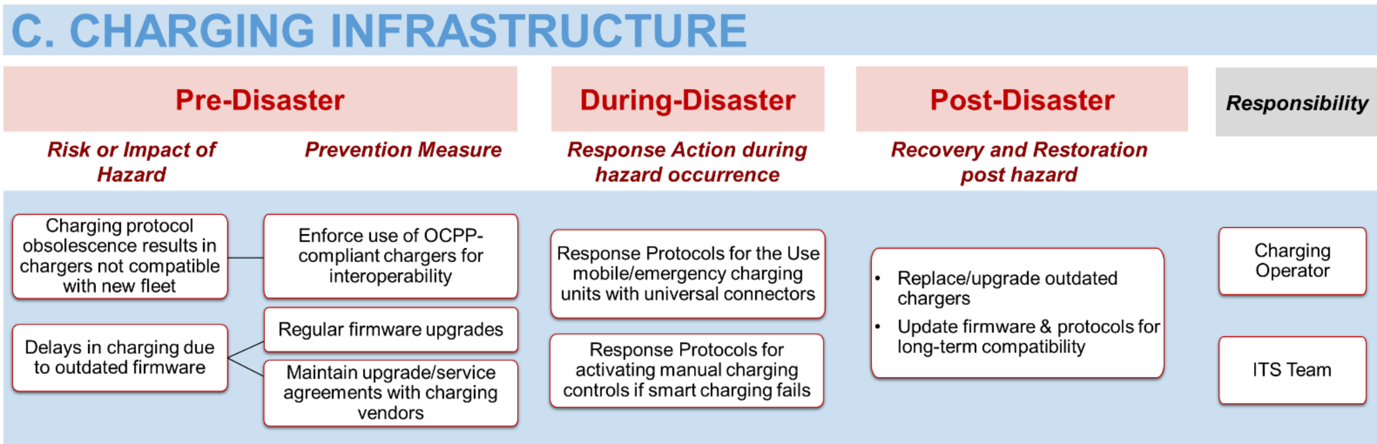



Exhibit 51Technological Obsolescence-specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery

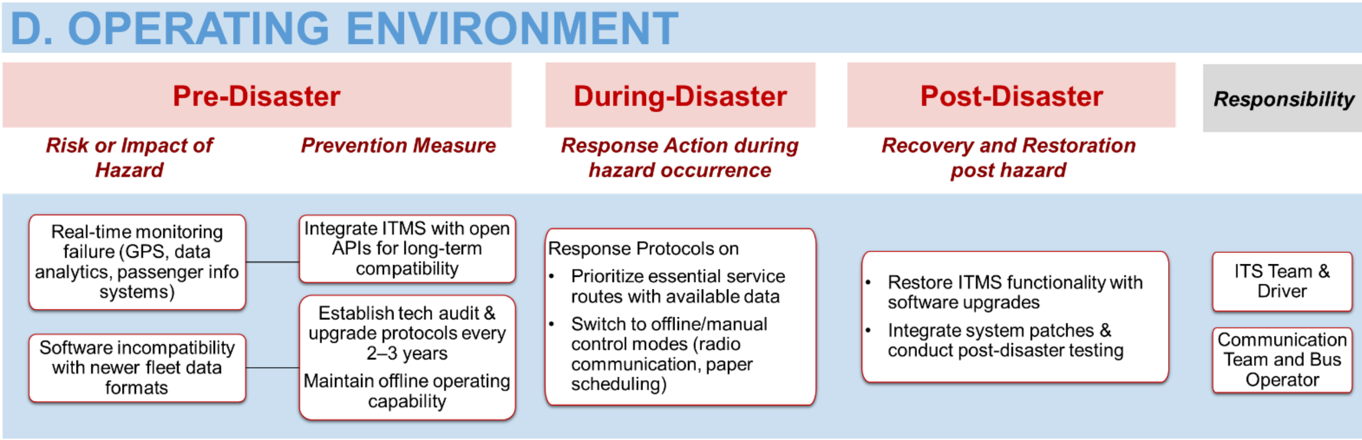



*Exhibit 52 Technological Obsolescence-specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.8. Protest / Vandalism

The protests and vandalism pose significant operational and safety risks across the EBES. These incidents can result in physical damage to buses, depots, chargers, and roadside assets; disrupt routes and charging schedules and threaten safety of passengers and staff. Fleets are vulnerable to vehicle damage and forced service suspension, depots face risks of trespassing and sabotage, charging infrastructure is exposed to tampering and electrical damage, and the operating environment experiences service disruptions and passenger inconvenience.

Risk and impact mapping identifies the need for layered resilience measures across all phases. Preventive actions include perimeter security, CCTV surveillance, tamper-proof enclosures, access control, and coordination with local law enforcement. During incidents, response strategies focus on rapid service diversion, secure fleet relocation, controlled depot shutdowns, and emergency communication. Post-incident measures emphasize damage assessment, asset repair or replacement, insurance claims processing, and phased restoration of services. The accompanying infographics detail component-specific risks and pre-, during-, and post-disaster strategies to protect assets and lives, ensure operational continuity, and enable swift recovery.

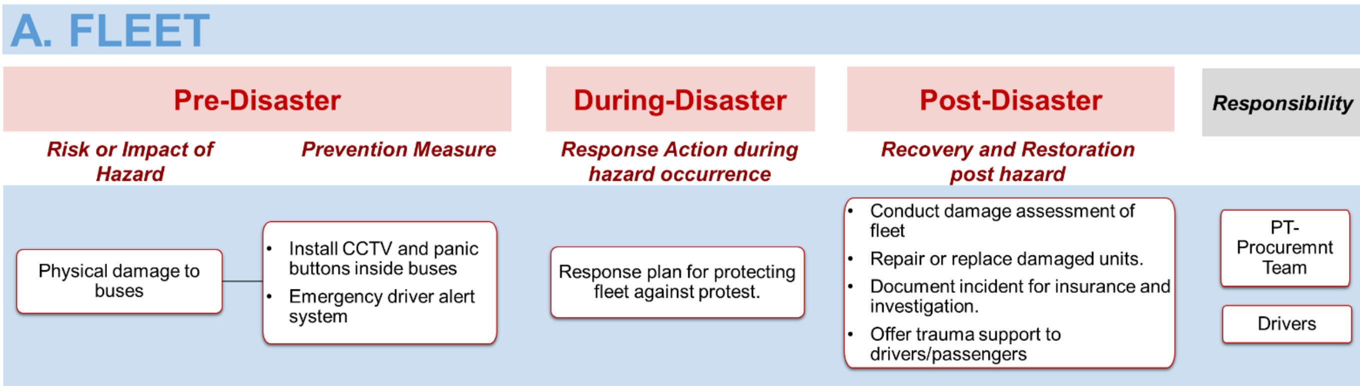



*Exhibit 53 Protest/Vandalism-specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

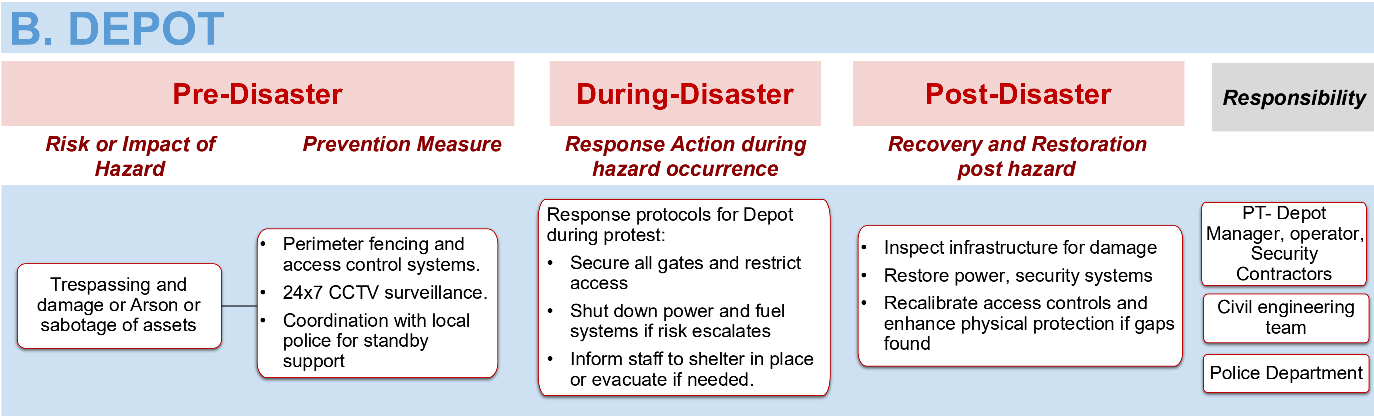



*Exhibit 54 Protest/Vandalism-specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

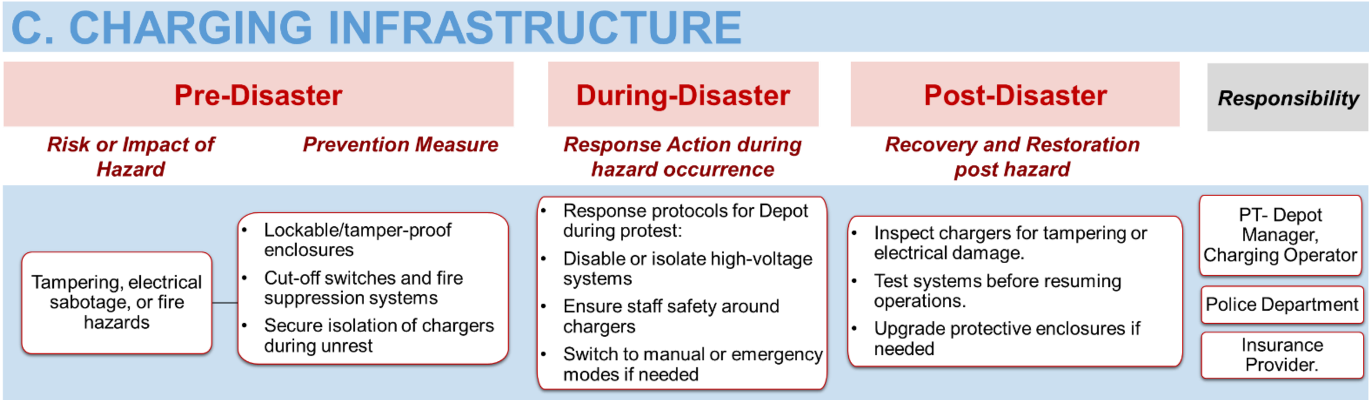



*Exhibit 55 Protest/Vandalism-specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

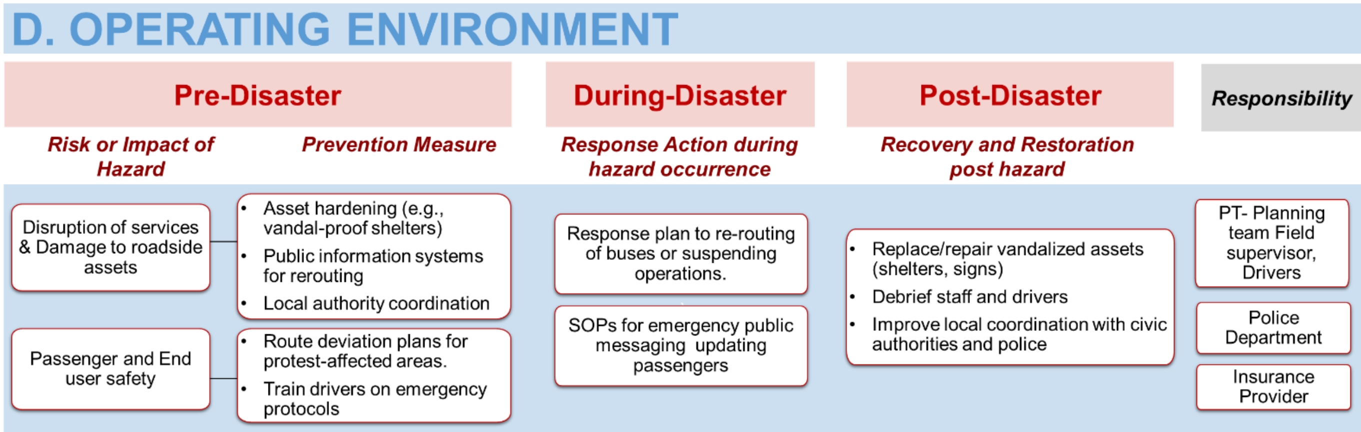



*Exhibit 56 Protest/Vandalism-specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.9. Traffic & Operational Accidents/ Human Negligence

Traffic and operational accidents, often arising from human negligence, pose critical safety and operational risks across the EBES. These incidents include vehicle collisions, battery damage leading to thermal runaway or fires, injuries to passengers, staff, or other road users, asset damage, and service disruptions. The impacts cut across all components such as fleets face collision damage, battery hazards, and fire risks; depots are vulnerable to on-premises accidents and cascading fire spread; charging infrastructure is exposed to vehicle impacts and equipment damage; and the operating environment experiences service interruptions due to congestion, road conditions, and interactions with third-party traffic.

Resilience measures span through the pre, during, and post-incident phases, including preventive driver training, defensive driving and fatigue management, capacity building among the staff and technicians, collision-resistant bus design, safe depot layouts, protected charging zones. During disaster there should be real-time emergency response protocols, and post-incident recovery actions such as asset repair, root-cause analysis, and phased service restoration. The accompanying infographics detail component-specific risks and targeted strategies to safeguard lives, protect assets, and ensure operational continuity.

## A. FLEET

| Pre-Disaster | | During-Disaster | Post-Disaster | Responsibility |
|---|---|---|---|---|
| Risk or Impact of Hazard | Prevention Measure | Response Action during hazard occurrence | Recovery and Restoration post hazard | |
| Collision due to road conditions, driver error, or equipment failure | • Defensive driving training<br>• Use of ITMS for real-time monitoring, video incident detection and speed monitoring<br>• Preventive vehicle maintenance<br>• Fatigue management SOPs | • Response plan for driver during traffic accident<br>• Stop vehicle, activate hazard signals<br>• Inform control room<br>• Evacuate passengers• Call emergency responders | • Inspect and repair damaged vehicle<br>• File incident report<br>• Analyze root cause<br>• Conduct driver retraining (if needed) | PT- Control Room, Planning team<br><br>Drivers |

*Exhibit 57 Traffic & Operational Accidents/ Human Negligence – specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## B. DEPOT

| Pre-Disaster | | During-Disaster | Post-Disaster | Responsibility |
|---|---|---|---|---|
| Risk or Impact of Hazard | Prevention Measure | Response Action during hazard occurrence | Recovery and Restoration post hazard | |
| On-premise collisions or mis-parking during ingress/egress | • Defined internal traffic lanes and depot circulation plans<br>• Clear markings and mirrors<br>• Speed limit enforcement<br>• Installation of CCTV and ITMS<br>• Installation of appropriate lightening | Response protocol during traffic accident at depots<br>• Suspend movements in affected area<br>• Alert depot manager<br>• Secure impacted zone | • Repair damaged assets<br>• Review internal traffic rules<br>• Conduct internal audit / drill review | PT- Depot Manager, Operator<br><br>Safety Officer, Security Contractor |

*Exhibit 58 Traffic & Operational Accidents/ Human Negligence -specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## C. CHARGING INFRASTRUCTURE

| Pre-Disaster | | During-Disaster | Post-Disaster | Responsibility |
|---|---|---|---|---|
| Risk or Impact of Hazard | Prevention Measure | Response Action during hazard occurrence | Recovery and Restoration post hazard | |
| Crash into charger or charger malfunction during movement | • Physical bollards for charger protection<br>• Marked safety zones<br>• Driver awareness SOPs<br>• Anti-rollaway features | • Response protocol during traffic accident at Charging infrastructure<br>• Immediately cut power<br>• Alert electrical team<br>• Evacuate and secure area | • Test charger and connections<br>• Repair or replace hardware<br>• Conduct incident review and update safety SOPs | PT- Charging Operator, Power Utility Vendor<br><br>Electrical Safety Officer |

*Exhibit 59 Traffic & Operational Accidents/ Human Negligence -specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

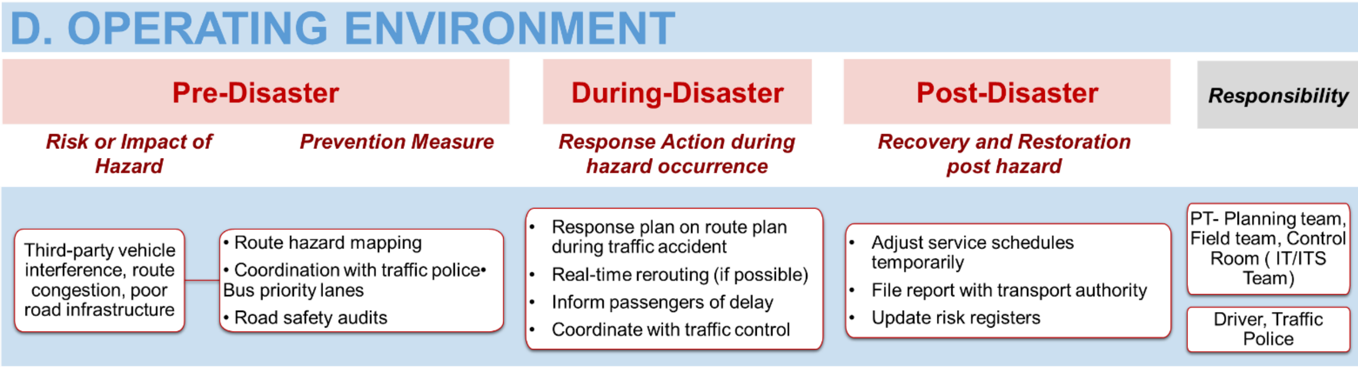



*Exhibit 60 Traffic & Operational Accidents/ Human Negligence -specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## 5.10. Knowledge Gaps/ Management Lapse

Knowledge gaps and management negligence pose systemic safety and operational risks across the EBES. These incidents include vehicle collisions, operational errors, improper handling of charging equipment, and lapses in maintenance, which may escalate into injuries, asset damage, fires, or battery thermal runaway, leading to service disruptions. The risk mapping highlights the need for strong preventive measures such as structured training, safety drills, and strict enforcement of SOPs; real-time response protocols including emergency medical aid, isolation of affected assets, and coordinated recovery; and post-incident actions focused on root-cause analysis, retraining, SOP refinement, and phased service restoration.

Across components, fleets are impacted by driver errors and vehicle mishandling, depots by unsafe equipment handling and inadequate supervision, charging infrastructure by improper EVSE operation, and the operating environment by control-room and scheduling lapses. The accompanying infographics present component-specific risks and resilience strategies across the pre-, during-, and post-disaster phases to safeguard lives, protect assets, and ensure operational continuity.

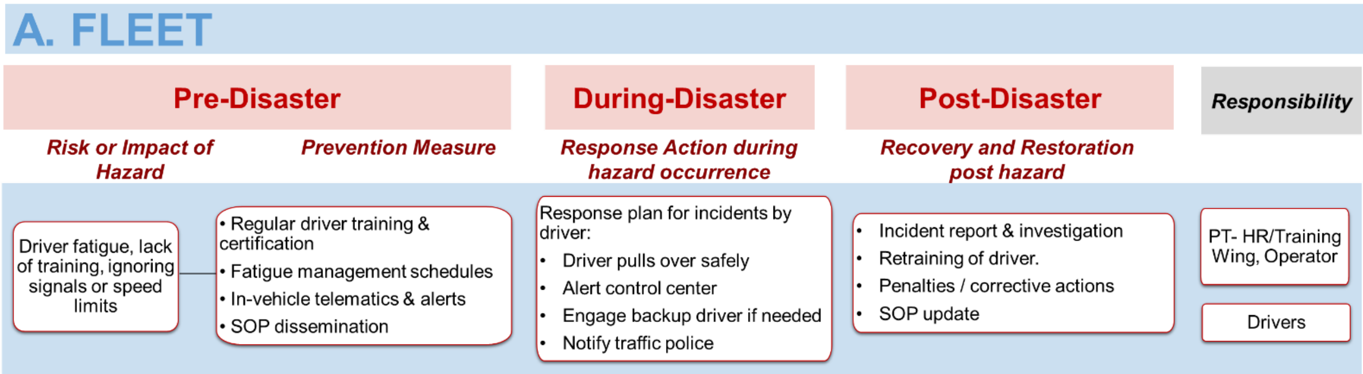



*Exhibit 61 Knowledge Gaps/ Management Lapse - specific Fleet-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery*

## B. DEPOT

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Unsafe handling of equipment, improper parking, inadequate supervision | • Staff SOPs for depot safety<br>• Surveillance & monitoring<br>• Entry/exit control & signage<br>• Role-specific training | Response protocol during human negligence incident at depots<br>• Stop depot operations in affected area.<br>• Alert depot manager & safety officer<br>• Evacuate if needed | • Investigate cause.<br>• Repair damaged infrastructure.<br>• Staff retraining & role clarification | PT- Depot Manager, Operator<br>Drivers |

Exhibit 62 Knowledge Gaps/ Management Lapse -specific Depot-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery

## C. CHARGING INFRASTRUCTURE

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Improper handling of chargers, skipping safety checks, failure to shut down during maintenance | • Electrical safety training<br>• Lockout-tagout procedures<br>• Regular equipment audits<br>• Checklists before operation | Response protocol during human negligence incident at Charging infrastructure<br>• Shut off power supply immediately.<br>• Evacuate & secure area.<br>• Notify electrical safety team | • Inspect all components.<br>• File safety report.<br>• Reinforce training.<br>• SOP updates | PT- Depot Manager, Charging Operator<br>Electrical Safety Officer |

Exhibit 63 Knowledge Gaps/ Management Lapse -specific Charging Infra-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery

## D. OPERATING ENVIRONMENT

| Pre-Disaster: Risk or Impact of Hazard | Pre-Disaster: Prevention Measure | During-Disaster: Response Action during hazard occurrence | Post-Disaster: Recovery and Restoration post hazard | Responsibility |
|---|---|---|---|---|
| Traffic controller errors, dispatch miscommunication, route planning mistakes | • Standardised control room protocols<br>• Staff rotation & supervision<br>• Use of ITS for real-time tracking<br>• Regular drills | Response plan for on route incidents of human negligence<br>• Pause bus operations on affected route<br>• Real-time correction via control room<br>• Notify stakeholders | • Root cause analysis.<br>• Cross-department debrief.<br>• Corrective action planning | PT- Field team, Control Room ( IT/ITS Team), Depot manager<br>Driver, Police station, Traffic Police |

Exhibit 64 Knowledge Gaps/ Management Lapse -specific Operating Environment-level Strategy for Pre-disaster, During Disaster and Post Disaster Recovery

# PART B:

# The E-Bus Disaster Readiness Blueprint

Pre- Disaster Planning | During Disaster Response | Post Disaster Recovery

Part B serves as a practical guide for building a resilient EBES by addressing hazard-specific impacts and operational challenges. The blueprint outlines hazard-specific strategies, tailored to the unique operational and technical needs of e-buses, ensuring alignment with both global best practices and local conditions. Recommendations are structured across **pre-disaster preparedness**, **real-time response during the event**, and **post-disaster recovery** covering infrastructure protection, operational continuity, emergency communication, and restoration protocols.

Collectively, these measures provide a step-by-step, actionable framework as illustrated in the exhibit below, to safeguard assets, ensure service continuity, and accelerate recovery, thereby embedding resilience at the core of e-bus operations.

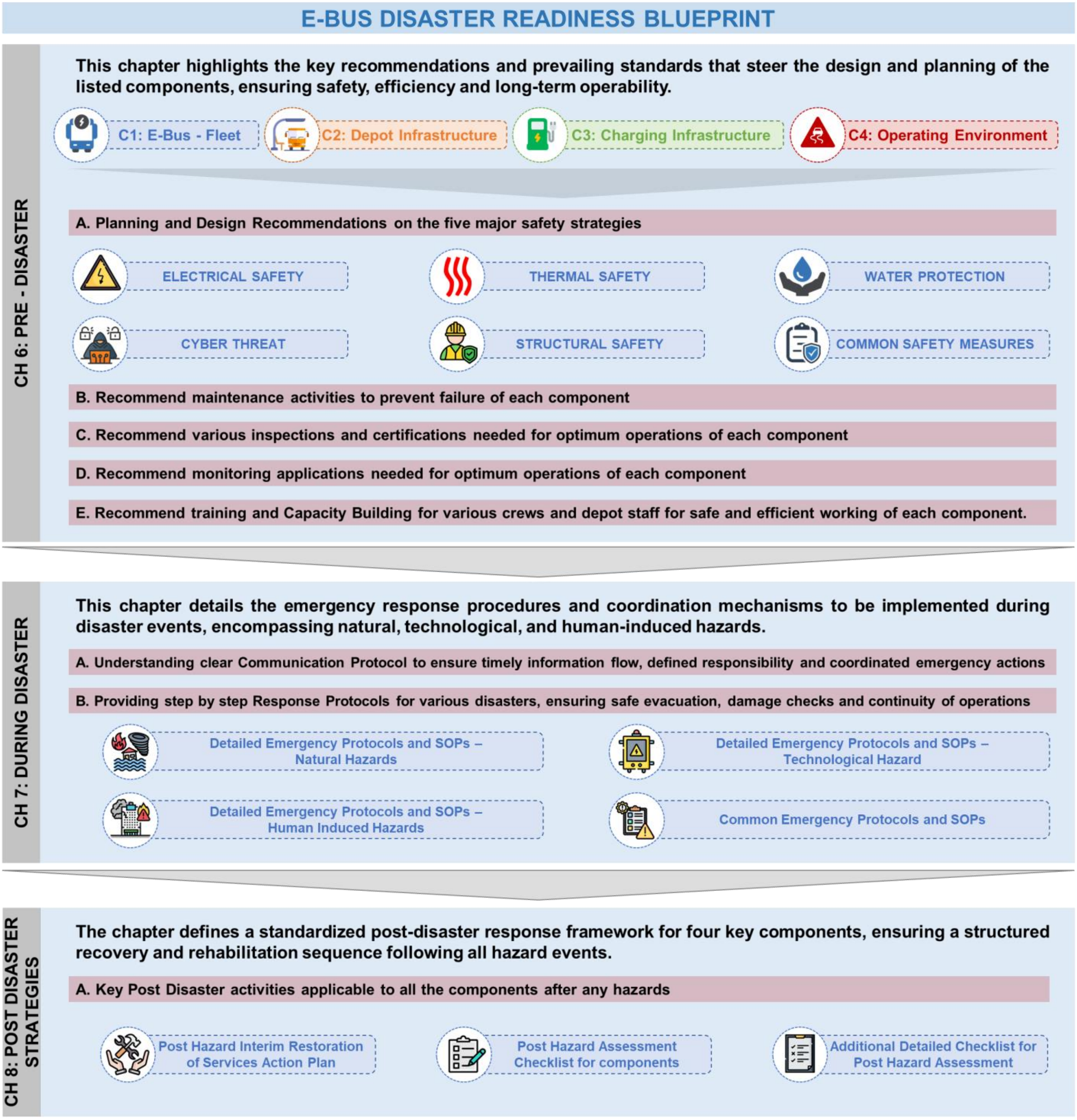



*Exhibit 65 Actional Framework of E-Bus Readiness Blueprint*

# 6. Pre-Disaster: Design and Planning Recommendations

A robust and resilient EBES begins with sound designs and meticulous planning at the pre-procurement and pre-construction stages. This section outlines key recommendations and prevailing standards that guide the development of various components and sub-systems of the EBES, ensuring safety, efficiency, and long-term operability. These include detailed technical and safety specifications for the **buses, charging infrastructure, depot layout and facilities planning, and operating environment.** In addition to greenfield depots, the document provides special attention for brownfield depots transitioning from ICE to e-bus operations. Enhancing the resilience of such depots requires a combination of engineering measures such as upgraded electrical systems, fire safety infrastructure, and improved drainage, and non-engineering measures such as staff capabilities, operational protocols, and capacity building.

Attempts are made to align the recommendations of e-bus specifications with end-user requirements of commuter convenience, comfort, safety, security and those related to fire detection, suppression and alarm system. Accordingly, these recommendations are harmonised with relevant Indian regulatory frameworks/ standards and guidelines including but not limited to those of **CMVR, AIS, UBS, BIS and other best practices and norms laid out by fire safety and state disaster management agencies** as well as **original equipment manufacturers (OEMs)**. The bus design are mandatorily required to **be type approved by government authorised testing agency** such as ARAI, ICAT, NATRaX or CIRT etc to ensure regulatory and safety compliances. Together these measures ensure climate resilience, technological reliability, operational safety and readiness across diverse operating conditions. A detailed checklist of the applicable national and international standards for various EBES components is provided in Annexure B, C and D for reference.

The comprehensive design and planning recommendations for fleet, depot infrastructure, charging infrastructure and operating environment are provided here under:

## 6.1. Component 1: Fleet

At the stage of procurement, design and safety specifications for e-buses are laid out based on passenger convenience and comfort, structural sturdiness and safety under static and dynamic loadings, besides overall operational performance requirements to ensure operational efficiency, safety, and service reliability under diverse operating conditions. Indian Standards such as AIS 052, AIS 153 and other AISs, UBS II, BIS and the regulatory requirements of CMVR, amongst other relevant standards govern various design features and procurement aspects of e-buses. These standards, inter alia address various aspects, including e-bus body design, energy storage system (primarily in high-capacity lithium-ion battery packs), propulsion systems, transmission and drivetrain and cooling systems.

Basis type (I, II, III, IV as per AIS 052) of operations, travel demand intensity, route network geometry and other characteristics, operational performance requirement with reference to operating range, gradeability and acceleration, the overall capacity of battery packs for e-buses is decided. The e-bus structure is required to be designed and evaluated for buckling strength, vibrational stability, structural integrity, crashworthiness in the event of frontal and side collisions, roll over protection etc., as per loading conditions and performance requirements detailed in Annexure B here and the UBS II to obtain overall safety of e-bus design.

## A. Planning & Design Standards

At the procurement stage, key design and safety requirements for e-buses are defined to ensure structural stability, safety, operational efficiency, and reliable performance under diverse operating conditions. These requirements also include inbuilt design features and their evaluation mechanisms using Finite Element Analysis (FEA) and stage wise quality assurance systems that improve robustness, reduce failure risks and strengthen disaster resilience. Procurement teams play a critical role by clearly embedding these standards and specifications in tender and procurement documents to ensure that OEMs adhere to these requirements during design, fabrication, delivery and operations. OEMs, in turn, are expected not only to comply with the requirements set by Public Bus Transport Agencies[9] but also to continuously improve sturdiness, safety and resilience through ongoing research, development, and innovation. While the planning and design standards are organized into the following critical safety categories, detailed planning and standard recommendations are presented in the respective sections.

### I. Electrical Safety

#### *Planning Recommendations*

*Table 3 Stakeholder-Specific Electrical Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **ELECTRICAL SAFETY** | | |
| **1.** | Provide dual-Socket Charging in E-Bus | Procurement Team, OEM |
| **2.** | Provide Fuses, circuit breakers and surge protection device | Procurement Team, OEM |
| **3.** | Ensure optimal condition of battery packs at e-bus acquisition stage | Procurement Team, Planning Team |
| **4.** | Provide for timely Replacement of battery packs | Procurement Team, OEM |
| **5.** | Develop safe charging practices and protocols | OEM |
| **6.** | Provide mitigation of electrocution risk in e-buses | Procurement Team, OEM |

- **Provide dual-Socket Charging in E-Bus:** The OEM and procurement team of public bus transport agencies to provide dual socket charging in e-buses to facilitate flexible bus parking (either direction) enable charging access from both sides or ends, reduce infrastructure points, save space and optimise depot layout plans.
- **Provide Fuses, circuit breakers and surge protection devices:** These provisions designed to protect the e-bus electrical system from overloads, short circuits and be easily accessible.
- **Ensure optimal condition of battery packs at e-bus acquisition stage:** Public bus transport agencies are advised to ensure that the supplied battery packs are safety certified by the authorised organisation at the time of the acquisition. At the time of acquisition, the battery packs be less than six months old, to obtain optimal performance and safety from the outset.

[9] Public Bus Transport Agencies that manage public bus services in urban cities such as State Transport Undertaking (e.g. Karnataka State Road Transport Corporation), Municipal Transport Undertaking (e.g. Bengaluru Municipal Transport Corporation) and Special Purpose Vehicle (e.g. Sitilink, Surat).

- **Provide for timely replacement of battery packs:** Follow preventive replacement or safe repurposing of traction battery pack systems **after 5–6.5 years[10] of use or completion of 2500-3000 cycles[11] or when the State of Health (SoH) falls below 80%**, to ensure continued safety and reliable performance. Public bus transport agencies are advised to include a clause on 'sharing a proof of battery health' in the tender document, to enable effective battery performance monitoring by public bus transport agencies.
- **Develop safe charging practices and protocols:** Avoid **deep discharging** by initiating charging when the battery charge level drops to **10-20%** and prevent **overcharging** by maintaining an optimal charge level between **85-90%[12].**
- **Provide mitigation of electrocution risk in e-buses:** Use of armoured cables, cable route marker, proper lightning protection and earthing mechanisms are advised to be incorporated in all vehicles as per the requirement specified in respective safety standards.

***Design Standards***

The following standards amongst others, shall be incorporated into e-bus designs by the OEM and verified by the procurement team. A detailed list of applicable standards is placed at Annexure B.

- For **electric propulsion systems**: **AIS 048 and AIS 049.**
- **Construction and Safety requirements of e-buses:** AIS 038, battery thermal management, use of liquid cooling systems to maintain battery temperatures between 15°C to 35°C.
- **Traction Motors:** The electric traction motor which may be either a single in-line motor[13] or wheel hub motors[14] are to be equipped with an **overheating warning and an overheating protection system**[15]**.** When the overheating warning is triggered, the motor's power be reduced (derated) to lower the temperature and to avoid further risk of overheating or permanent damage. The motors should also have **IP 67/68** protection against water and dust ingress.

**RECOMMENDED STANDARDS**

- *Safety Specification for batteries: ISO 6469 Series*
- *Battery Packs - Impact Testing: SAE J2464; Testing under vibration: SAE J 2380 2021*
- *Safety Standard for Li-battery: SAE J 2929-2013*
- *Safety related warning labelling practice for batteries and other items: SAE J 2936 2025*
- Recommended Practice for Transportation and Handling: SAE J 2950-2020
- Traction Motor protection against water & dust Ingress: IP67/68

[10] Source: Internal Discussions with experts and Workshop Insights
[11] Source: Internal Discussions and Workshop Insights
[12] Zenobe - Electric bus battery degradation
[13] Single in-line motor: a central motor that drives the wheels via a drivetrain
[14] Wheel hub motor: motor directly mounted on each wheel
[15] MTC- RfP specification for 12m Electric Bus

## II. Thermal Safety

### *Planning Recommendations*

*Table 4 Stakeholder-Specific Thermal Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **THERMAL SAFETY** | | |
| **1.** | Minimal battery exposure to direct heat through battery positioning | Procurement Team, OEM |
| **2.** | Preferred operating temperature range of the on-board cooling system | Procurement Team, OEM |
| **3.** | Fire Detection and Suppression Systems (FDSS), Fire alarm and FPS for passengers | Procurement Team, OEM |
| **4.** | Compartmentalised Fire Zones on board | OEM |
| **5.** | Preferred charging period for batteries for optimal temperature range | OEM |
| **6.** | Parking of E-Buses particularly during charging process | OEM |
| **7.** | Battery Management System (BMS) | Procurement Team, OEM |
| **8.** | Monitoring Battery Temperature and safe operating temperature range indicator | OEM |
| **9.** | Battery discharge Alerts and provision for SOH alerts | OEM |

- **Minimal battery exposure to direct heat through battery positioning:** In **high temperature operating regions**, position battery modules at the **belly/ under floor level of e-buses** to minimise exposure to direct heat for enhancing thermal protection.
- **Preferred temperature range of the on-board cooling system:** As the e-bus battery naturally performs well **in temperature range of 15°C and 35°C,**[16] maintaining this temperature range is crucial for maximising battery performance, lifespan, and safety by proving an efficient battery cooling system.
- **Fire Detection and Suppression Systems (FDSS), Fire alarm and FPS for passengers:** Installation of FDSS near fire sensitive areas especially the battery packs is recommended, to timely detect and suppress any fire. Also provide a fire alarm to simultaneously alert passengers and the staff for timely evacuation, etc. FPS in passenger compartment need also be provided for pax safety.
- **Compartmentalised Fire Zones on board:** Design to position battery packs in separate compartments, located away from driver work area, and passenger cabin to enhance crew and occupant safety.

[16] Renewable and Sustainable Energy Reviews; Review of battery thermal management systems in electric vehicles; 2024

- **Preferred charging period for batteries for optimal temperature range**: Charging of the battery to be undertaken preferably during cooler hours.
- **Parking of E-Buses particularly during charging process:** Park e-buses under shaded and adequately ventilated spaces particularly during charging.
- **Battery Management System (BMS): The BMS** functions as an intelligent monitoring and control unit for the battery packs besides other items. It comprises integrated hardware and software, with hardware embedded within e-bus systems, to monitor different parameters of battery components and other items. The BMS continuously tracks key parameters such as State of Charge (SoC) estimation, state of health (SOH), useful residual life, power availability, depth of charge and discharge, voltage and current fluctuations and temperature. It also supports thermal management, safety monitoring, communication, computation and real time data logging to ensure safe and reliable battery operations.
- **Monitoring Battery Temperature and safe operating temperature range indicator:** During operations, if the battery temperature is observed to exceed 32-35°C[17] or other OEM prescribed range, safety mechanisms such as switching e-bus to crawl mode, gradual reduction in acceleration etc. are advised.
- **Battery discharge Alerts and provision for SOH alerts:** Drivers are to be trained to respond promptly to battery discharge alerts. The first alert may be triggered at 30%[18], displaying details of the nearest charging station. Subsequent alerts may occur between 25–21%. Below 20%, the bus enters crawl mode, and the driver is instructed to stop the vehicle at a safe location to prevent deep discharge that could potentially imbalance the battery composition.

***Design Standards***

The following standards shall be incorporated into e-bus designs by the OEM and the procurement team. A detailed list of applicable standards is placed at Annexure B.

- **Safety standards such as AIS 052, AIS 153, AIS 135, UBS II, UNECE R100, R107, R66, R95, R29, FMVSS 302 and 305** provide detailed requirements for various safety and other aspects of e-buses. These, inter-alia include mandatory measures for over-temperature protection, lightning protection, installation of fire extinguishers, FDSS use of fire-retardant materials in bus bodies, and the Battery Management System (BMS) capable of initiating a three-step disconnection process in case of identified risks.
- **Battery Chemistry:** Use of **$LiFePO_4$ (LFP) batteries**, which have better thermal stability compared to NMC/NCA chemistry-based batteries. Additionally, battery modules be compliant with UN Manual of Tests and Criteria Part III, subsection 38.3 and relevant provisions of AIS 156.
- **Battery Cooling Systems:** Use a coolant /gel-based battery cooling system (e.g. glycol gel) to

**RECOMMENDED STANDARDS**

- *Thermal Safety Specification for e-buses: AIS 052, 153, 135, 156*
- *Fire safety specification related to Electrical Installations: IS 1646:1997*
- *Internation Standards on Thermal management & fireproof battery enclosures: UNECE R100 & R107*
- *FDSS Specification in public transport vehicles: FMVSS 302 and 305 & EN 1839*

[17] Source: Internal Discussions with experts and Workshop Insights
[18] Source: Internal Discussions with experts and Workshop Insights

maintain battery temperature in the optimal range of 24°–32°C[19]. This process typically takes 5–6 minutes, after which the e-bus powertrain starts.

- **Other Battery Safety Features:** Include **over-voltage and under-voltage protection**, **over-current protection, thermal runaway prevention** (using phase-change materials or fire-resistant barriers), and cell balancing and short-circuit protection. For fire safety thermal fuses or venting mechanisms shall be provided.
- **Interior materials and wire insulation** within the bus be made of **fire-retardant**, low smoke compounds to enhance fire safety.
- Use of **UV-resistant paints and plastics be made** to reduce material degradation.
- **HVAC servicing:** OEMS to provide for and ensure implementation of optimal serving schedules of the HVAC system particularly, before and during summer season.
- Provide cabin Insulation using insulation films or blinds and installing roof insulation sheets or reflective paints.
- **Provision of on-board Fire extinguishers:** Battery compartments are advised to be fitted with FDSS systems and simultaneous with fire alarms and FPS in passenger compartment. **ABC dry powder fire extinguishers** are advised to be provided in other high-risk zones such as passenger compartments to safeguard the area from Class A (combustibles), Class B (flammable liquids), and Class E (electrical Equipment)[20] fires; ensuring early containment of thermal events, as per IS 2190:2010 guidelines. International standard NFPA 10, outlines requirement for portable fire extinguisher as the first line defence against fires of limited size.
- **Compliance with Safety Standards:** Global benchmarks including **UN standards like ECE R100 and R107** emphasize thermal management, fireproof battery enclosures and safety integrity. Federal Motors vehicle standards FMVSS 302 and 305, and EN 1839 are some of the standards for installation of FDSS in public transport vehicles[21].

## III. Water Protection

### *Planning Recommendations*

*Table 5 Stakeholder-Specific Water Protection Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **WATER PROTECTION** | | |
| **1.** | Battery placement and bus floor height | Procurement Team, OEM |
| **2.** | Water Sensors | Procurement Team, OEM |
| **3.** | Automatic Power Cutoff in case of water ingress: | Procurement Team, OEM |

- **Battery placement and bus floor height:** Battery placement may be determined judiciously based on local conditions. The battery packs may be suitably fitted on rooftop, and across other suitable locations such as the rear end or other architecturally unused spaces while

[19] Source: Internal Discussions with experts and Workshop Insights
[20] Types of Fire Extinguishers & Uses
[21] https://www.mdpi.com/2571-6255/8/4/159

ensuring the bus remains low-floor and accessible to all passengers. In flood prone areas, floor mounted batteries may be avoided to minimise the risk of water ingress and damage.

- **Water Sensors:** Install water sensors near high voltage modules to enable automatic isolation of these modules upon detection of water ingress.
- **Automatic Power Cutoff in case of water ingress:** The system may be designed to automatically isolate power to prevent damage, and low-voltage circuits such as door systems are recommended to be protected by using fuses and relays.

***Design Standards***

The following standards shall be incorporated into e-bus designs by the OEM and the procurement team. A detailed list of applicable standards is placed at Annexure B.

- **Water and Dust Ingress protection:** Ensure that battery packs, motor enclosures, connectors, and wiring systems are adequately protected against dust and water ingress. The e-bus components with ingress protection rating of **IP67 and IP68** are recommended for complete protection in dusty and polluted environments[22].
- **Corrosion Prevention:** In coastal or high humidity regions, use IP68 compliant and corrosion-resistant materials or protective coatings to prevent battery damage from salt-laden air and moisture exposure.

**RECOMMENDED STANDARDS**

- ***IP67:*** *high resilience to water exposure up to 1 m depth for 30 mins*
- ***IP68****: longer submersion (up to 1.5 meters depth) for a maximum of 30 minutes.*

- All **electrical wiring, controls and connectors** are recommended to meet at least IP67 standards, in line with AIS 153 and UBS II, to ensure system resilience in varying environmental conditions.
- All connectors are recommended to have **inbuilt waterproof plugs** for unused terminal and features a **360° seal to prevent water ingress**. External rubber components or sealing applications may be added to connectors or other parts that require additional protection.

## IV. Cyber Security

*Table 6 Stakeholder-Specific Cyber Security Mitigation Measures*

| S.N. | Activities | Responsibility |
| --- | --- | --- |
| **CYBER SECURITY** | | |
| **1.** | Secure Electric Control Unit (ECU) Communication | Procurement Team, OEM |
| **2.** | Protect Controller Area Network (CAN) Networks | Procurement Team, OEM |
| **3.** | Verify Firmware Integrity | OEM |
| **4.** | Deploy System Firewalls | Procurement Team, OEM |
| **5.** | Restrict Physical Access to on-board ports | OEM |
| **6.** | Integrate digital-Physical Data for improvement | OEM |

[22] IP 68 Protection Rating, Poly Case

- **Secure Electric Control Unit (ECU) Communication:** Secure by ensuring that ECUs are equipped with encrypted communication protocols and authentication mechanisms.
- **Protect Controller Area Network (CAN) Networks:** Implement message authentication and encryption on CAN buses to prevent spoofing, unauthorised access and data tampering.
- **Verify Firmware Integrity:** Regularly verify firmware integrity and apply digitally signed updates.
- **Deploy System Firewalls:** OEMs are advised to include firewall protection across all portals and systems. Further, provide for monitoring the data through Condition Monitoring System (CMS) and Supervisory Control and Data Acquisition (SCADA) platform.
- **Restrict Physical Access to on-board ports:** Restrict access to On-board diagnostics (OBD) ports and infotainment systems; disable unused physical ports (USB, SD).
- **Integrate digital-Physical Data for improvement**: Combine real time data from the cyber and physical domains to improve awareness.

## V. Structural Safety of battery installation

*Table 7 Stakeholder-Specific Structural Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **STRUCTURAL SAFETY** | | |
| **1.** | Provision of mechanism to protect against pressure build ups | Procurement Team, OEM |
| **2.** | Provision for reinforce Battery Casing | Procurement Team, OEM |
| **3.** | Avoid Vulnerable Parking | STU/ Public Transport Authority |
| **4.** | Link Uptime Contracts | Procurement Team |
| **5.** | Safety certification and residual life | Procurement Team, OEM |
| **6.** | Maximum serviceable life of e-buses | Procurement Team, OEM |
| **7.** | Enhance driver support system | Procurement Team, OEM |

- **Provision of mechanism to protect against pressure build ups:** Install pressure release valves in the lower section of the battery packs to manage internal pressure buildup safely[23].
- **Provision for Reinforce Battery Casing:** A reinforced casing is provided around the battery to protect it from structural damage due to external impacts.
- **Avoid Vulnerable Parking:** Avoid parking near unreinforced buildings.
- **Link Uptime Contracts:** Implement contracts that link fleet uptime and safety performance to timely battery replacement schedules, incentivizing preventive maintenance over reactive repair.

**RECOMMENDED STANDARDS**

- ***Safety Certification and Residual Life:*** *IS 17855 (Part 2) and IEC 62660-2*

[23] https://www.mdpi.com/2571-6255/8/4/159

- **Safety certification and residual life:** The OEM or battery supplier to provide independent safety certification and residual life analysis for any battery packs proposed for secondary use, in line with standards such as IS 17855 (Part 2) and IEC 62660-2. Structural safety and sturdiness requirements of buses are also available in UBS II.
- **Maximum serviceable life of e-buses:** The maximum serviceable design life of e-buses may be limited to 8-10 years, keeping in view the operating environment, structural integrity under applicable loading conditions following accelerated evaluation of the structural design using FEA or otherwise.
- **Enhance Driver Support System:** Ensure installation of telematics with rear cameras and other dashboard instruments and tell-tale signals to enhance driver support system for improved bus and passenger safety and also protection of other road users.

## VI. General Safety Measures

*Table 8 Stakeholder-Specific General Safety Measures Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **GENERAL SAFETY MEASURES** | | |
| **1.** | Safe Driving Recommendations - Driver fatigue and driving safety | Procurement Team, OEM |
| **2.** | Safe Driving Recommendations - Driver Health and Safety | Depot & Central Workshop System |
| **3.** | Battery related safety sensors | Procurement Team, OEM |
| **4.** | Safety from Technological Obsolescence | Procurement Team, OEM |
| **5.** | Passenger Safety and Security Features | Procurement Team, OEM |

### *Safe Driving Recommendations*

Unsafe driving practices cause e-bus safety hazards and emergency incidents. To assist driver in safe driving, procurement team shall ensure that the tender documents include provision of an on-board driver assistance system for installation by the OEMs. Such systems support the driver In safe driving by early identification of potential hazards and providing timely warning for a corrective action, thereby encouraging safer driving behaviour.

- **Driver fatigue and driving safety**: Implement systems for continuous monitoring of driver fatigue level to enable corrective measures and ensure safe driving.
  - **Equipping buses with Advanced Driver Assistance System (ADAS):** ADAS system help improve driving safety by providing Collision Prevention Early Warning System (CPEWS) signals to guide the driver in timely course correction for safe driving. Provision of ADAS in e-buses is recommended.
  - **Equipping buses with Driving Fatigue Monitoring System (DFMS):** The system continuously monitors driver's alertness and behaviour using real-time driving safety & surveillance inputs, provides timely alerts and driving assistance and helps reduce fatigue related risks, thereby improving overall driving safety. Provision of DFMS in e-buses is recommended.

- **Equipping e-buses with Emergency Alerts:** Audio-visual alerts for abnormal behaviour of any sub-system of e-bus are recommended to be provided on driver dashboard for timely corrective action to avoid occurrence of any mishap.

- **Driver Health and Safety:** Poor driver health adversely affects driving behaviour and operation safety. The public bus transport agencies should conduct regular biannual health check-ups, including but not limited to eye sights tests, screening for night blindness, blood pressure and other age-related health conditions.

***Battery related Safety Sensors***[24]

Battery condition be regularly monitored for critical parameters using continuous feedback about such critical parameters for necessary corrective action. Three levels of battery condition monitoring and control provisions, as under, be mandatorily made in e-buses:

- **Level 1 is at Battery Level:** Every battery should come with an in-built thermostat, that monitors the temperature range and as soon as it exceeds the safety threshold, the protective mechanisms gets activated to electrically isolate the battery and prevent further energy discharge.
- **Level 2 is at the Battery Control Unit (BCU):** The BCU monitors battery performance during charging and discharging, including current flow, voltage balance, and thermal conditions. Upon detection of anomalies, the BCU initiates automatic cut-off to protect the battery system.
- **Level 3 is at the Master Control Unit (MCU):** At the vehicle level, the MCU receives alerts from the Battery Management System (BMS) when parameters such as temperature, vibration, or electrical faults exceed defined limits. Based on the critical levels of the parameter(s), the system initiates-controlled power reduction or brings the bus to a safe stop to prevent escalation of risk.

***Safety from Technological Obsolescence***

The procurement team of the public bus transport agencies, should include in the tender document, features like use of interchangeable spares, sub-systems and the technologies; provision of continual technological upgradation and long-term support of supplies, as follows amongst others:

- **Technology Upgradation:** OEMs of e-bus systems and sub systems to provide periodic upgrades for software and selected hardware based upon technological advancement whenever necessary.
- **Standardise Fleet Systems and sub systems:** public bus transport agencies need to ask OEMs for use of standardised, compatible and interchangeable systems/ sub systems across the fleets so that software and hardware can be easily updated or replaced in parts when needed.
- **Ensure Long Term Support:** public bus transport agencies should procure e-buses with long term (co-terminating with life of buses, normally 10 years or more) operational and maintenance support from the manufacturer.

[24] Source: Internal Discussions with experts

***Passenger Safety and security Features***

Following provisions related to passenger safety and security be provided in e-buses.

- **Display Safety Guidance:** Install safety-guide posters or messages inside the bus to assist passengers during emergencies.
- **Provide Fire Protection system in Passenger Compartment:** Equip compartment of e-buses with Fire Protection System (FPS) to facilitate its timely detection, alarm and control. The FPS should comprise of early detection sensors (smoke/ heat), sound alarm, and automatic activation of the high-pressure water mist cylinder/ pump module in case fire break outs.
- **Provide Emergency Equipment in Passenger Compartment:** Equip the passenger compartment with emergency provisions such as hammers to break the glasses, emergency exit door/ hatches for quick evacuation, fire extinguishers to douse fires, and safety signages for guidance in emergencies.
- **Enable Passenger Security:** Install CCTV and the panic buttons inside the e-buses for passenger safety and security.
- **Provide Passenger Seatbelts:** Provide seat belts at passenger seats particularly for those, without any supports/ handholds at front, seats facing aisle and those facing rearward, for improved safety in the event of any sudden acceleration /harsh braking/ accidents.

### *B. Maintenance Management and Activities*

To ensure efficient operations and enhance system resilience, it is recommended to adopt a two-tier, unit-replacement-based repair and maintenance management system for e-bus fleets. This approach minimises vehicle down time, optimises the use of skilled manpower and resources, and effectively addresses the technological complexities of e-buses.

Under this framework, Tier-1 (Depot Workshops) is responsible for routine preventive maintenance and roadworthiness certification, at scheduled intervals generally as prescribed by the OEMs and the certification agencies such as the State Transport Authority (STA). Further, day to day repairs and minor accidental repairs of e-buses are undertaken here as and when called for. Replacement of failed aggregates using pre-reconditioned or part-worn (PW) units is also carried out at this level to ensure quick turnaround and maintain fleet availability.

Tier – 2 (Central Workshop) handles major overhaul and repairs of critical aggregates such as traction motors, batteries, BMS, axles and other key components, along with repairs of severely damaged buses. It also undertakes specialized functions including procurement, quality assurance, inventory management, and maintenance of float units to support continuous operations.

The above distribution of repair and maintenance functions, activities and their management is generally termed as a “Two Tier Repair and Maintenance Management System” for public transport fleets. Besides optimal utilization of resources and the skill levels, this is conducive to enhance system resilience by providing robustness in repair and maintenance and the distributed resources. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 9 Stakeholder-Specific Maintenance Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Safe Maintenance Protocol | Depot & Central Workshop System, OEM |
| 2. | Scheduled Preventive and Corrective Maintenance OEM prescribed | Depot & Central Workshop System, OEMEB |
| 3. | Maintain Cyber Security | OEM |
| 4. | Optimise Battery Life through proper charging protocols | OEM |
| 5. | Repairs and retrofitting | Depot & Central Workshop System, OEM |
| 6. | Seasonal Preventive Checks | Depot & Central Workshop System, OEM |
| 7. | Routine Roadworthiness Certification of e-buses as per periodicity laid by the STA | Depot & Central Workshop System, OEM, STU/ Public Transport |
| 8. | Unit Replacement – failed units replaced by serviceable or pw units (out of serviceable float of units provided by CWS) | OEM |
| 9. | Return Damaged Batteries | Depot & Central Workshop System, OEM |

**OEMEB: OEM – E-Bus Operator*

All preventive maintenance activities be meticulously undertaken as per OEM prescribed schedules. These schedules are usually based on either time elapsed or kilometres operated by the bus. These tasks should be taken from the official service manuals provided by the e-bus manufacturers. Some These preventive maintenance schedules are as follows:

- Daily
- Weekly/ Fortnightly
- Monthly/ Quarterly
- Half Yearly/ Annually

- **Safe Maintenance Protocol:** While carrying out any repair or maintenance or inspection on an e-bus make sure that the following precautions amongst others are taken:
  - Apply wheel chokes on all wheels
  - Ensure ignition switch key is removed
  - Display "Do not Start the e-bus" on steering wheel
  - Display job card along with the tasks list at an appropriate location.
- **Scheduled Preventive and Corrective Maintenance OEM-Prescribed:** Additionally, some of the tasks specifically advised by the OEMs for e-buses are as here-under:
  - **Traction Cooling System:** Visually inspect the radiator, visually check the radiator core and if choked (dust accumulation), clean it. Inspect the sensor wiring harness and connectors for loose connections. Visually check the coolant level and top up if low/ below the mark and check for any leakage for corrective action.
  - **Battery Cooling System (BCS):** Visually inspect BCS for any coolant leaks and coolant level, and top up, if low.

  - **Electrical Connection:** Visually inspect all connections of high and low voltage components for looseness. Loose terminals may lead to arcing, overheating or system faults.
  - **High Voltage Battery:** Verify battery-related parameters and status through the bus dashboard by using cluster meter to ensure proper functioning of it. Additionally, inspect the battery for cleanliness, if dust or debris is observed, carryout appropriate cleaning.
  - **Electrical System:** Inspect the battery mounting and check that the tightening torque range is as prescribed by the specific OEM. Inspect the LV battery posts, terminals, & rubber boots. Inspect the conditions of HV cables for its clamping and fouling.
  - **Driver Console Dashboard:** Inspect and replaces switches, gauges, buzzers, light and driver controls at the driver console dashboard if found defective. Through cluster meter check or inspect for any error codes on display and rectify.
- **Maintain Cyber Security:** Conduct regular maintenance checks for the firewall inspection for various monitoring system and conduct regular cyber security updates.
- **Optimise Battery Life through proper charging protocols:** Battery packs life, generally corresponding to number of charging cycles, be optimised by following charging protocols laid by the OEMs to avoid over-charging and deep discharging. Batteries be charged by chargers with OEM specified charger rating and charging rates.
  - Ensure that the e-bus is taken up for charging before the residual charge level falls below the OEM prescribed limit to avoid deep discharge.
  - Charge batteries up to the max charge limit prescribed by the OEM to prevent overcharging.
  - Charging of batteries be carried out at optimal charging rate, preferably in shade and or adequately ventilated areas, to avoid overheating and thermal runaways. After operations, allow batteries to cool down before putting them on charge. Similarly following battery charging, allow cooling time before commencing bus operations.
  - Repair of power batteries must be carried out by certified technicians preferably at the central workshop (CWS).
  - Repair personnel shall wear insulation gloves, shoes and they are required to use insulated repair tools.
- **Repairs and retrofitting at Depot Workshop (DWS):**
  - Undertake minor repairs on day-to-day basis as required.
  - Attend to any electrical, short circuit, battery related defect as and when identified.
  - Ensure vehicle with identified defect is kept isolated till the defect is resolved.

Some of the other maintenance activities are discussed here-under:

- **Seasonal Preventive Checks:** Conduct preventive checks before on-set of summer/ rainy seasons and replace any vulnerable parts in advance.

- **Routine Roadworthiness Certification of e-buses as per periodicity laid by the STA:** Carryout routine in sections to ensure vehicle roadworthiness and system readiness in accordance with OEM defined task and periodicities (daily/ 10-Day/ monthly):
    - Verify vehicle starting condition, fault code, voltage etc
    - Visually check for coolant levels of the battery cooling system and top up, if low.
    - Inspect brake system, including checks for air leakages with brake pedal in both engaged and disengaged position.
    - Check charging interfaces, including charger flaps doors, connectors and related components for proper functioning.
    - Review dashboard alerts and error messages and initiate corrective actions as necessary.
    - Inspect electrical system, including BMS connections, electric motor connections, wiring harness panels, and ensure proper locking, sealing, and fitment of rubber gaskets.
    - Verify proper functioning of electrical fitments and accessories, including lighting systems (front and rear), LV batteries (clean terminals, check electrolyte levels where applicable), and other auxiliary systems.
    - Confirm functionality of Intelligent Transport Systems (ITS), Destination Display boards, CCTV cameras, communications systems, etc and address any identified deficiencies.
    - Ensure proper operation of passenger and emergency doors, confirming opening and closing within the prescribed time (e.g., within 4 seconds) and other safety features.
    - Attend to driver-reported complaints promptly to prevent escalation of faults.
    - Continuously update preventive maintenance schedules and tasks based on operational data, fault trends, and data-driven analysis to improve reliability, safety, and overall performance.
    - After operations provide cooling time before taking up any repair or maintenance activities on e-buses.
    - Carryout all repairs, retrofitment or removal of batteries and components etc, only with the help of trained and qualifies technicians.
- **Return Damaged Batteries:** Return all damaged batteries promptly to the OEM for inspection, corrective action and safe handling.

### C. Inspection and Certification

All systems, sub-systems and components particularly safety critical items, of new buses including e-buses must undergo inspection and type approval/ certification as per CMVR and other applicable standards. All the statutory approvals, test certifications and compliance documents be checked and compliance confirmed, before deployment of new e-buses by the inspection team and the safety officer. During operations, effective implementation calls for targeted inspection and necessary corrective actions by relevant stakeholder, generally as outlined in the following table for enforcement and compliance.

*Table 10 Stakeholder-Specific Inspection and Certification Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Regular Vehicle Inspection and Maintenance | Safety Officer, Operations/ Technical Team |
| 2. | Regular inspection of the mechanical and structural integrity of buses | Safety Officer, Operations/ Technical Team |
| 3. | Regular inspection for the interior safety features | Safety Officer, Operations/ Technical Team |
| 4. | Regular Inspection of technological systems /ITS and related sub-systems | Safety Officer, Operations/ Technical Team |

Regular inspection of e-buses is essential to ensure roadworthiness, operational safety, and system reliability. The following safety-critical systems and components shall be mandatorily checked during periodic inspections.

- **Regular Vehicle Inspection and Maintenance:** All e-buses should undergo comprehensive inspection periodically and roadworthiness certification by the designated transport authority at scheduled intervals. In absence of in-house capabilities, such periodical inspections may be contracted from qualified third-party /external agency. The checks for safety critical systems shall include the following critical items amongst other:
    - Electrical System – High voltage connections, terminals etc.
    - Charging ports for functionality
    - Emergency shutdown systems for operational performance.
    - Battery System – With specific focus on Battery Management System, battery cooling system and leakages, overheating, dashboard display of various system parameters, etc.
    - Overheating of traction and other motors, coolant levels in radiator.
    - Lighting system – headlights, indicator lights, brake lights, entry-exit lights for operational safety after sunset.
    - Steering system - for smooth operational performance, angle and height adjustments
    - Tyres for inflation, tread-ware indicators, cuts, abnormal tread wear, etc
    - Entry – exit doors for operational functionality, retraction when faced by resistance, prevention of vehicle movement with doors open,
        - Braking System – Air pressure and braking system leakages, breaking performance, brake liners and brake drums/ discs for wear, brake system, Anti-lock Braking Systems (ABS) and parking brakes performance.
    - Conduct regular firewall inspection and real time cyber security audits.
- **Regular inspection of the mechanical and structural integrity of buses:**
    - Inspect bus body condition for cracks, loose fastening, dents and any other visible physical damage.
    - Check chassis and bus body fasteners for tightness, alignment and structural integrity.
    - Inspect steering system and steering mechanism for wear, free play and proper functioning.

- Verify wheel alignment, king pin inclination and hub lubrication conditions.
- Inspect tyres for cuts, abnormal treadwear pattern and tread wear indicators.
- Check driver dashboard tell-tale signs, warning indicators and signalling systems for proper operation.
- Verify functionality of passenger information systems and onboard security cameras.
- Inspect reversing buzzer and camera for effective operations
- Check under-chassis components for damage, loose fittings or leakage.
- Inspect all lights & signalling device for proper illumination and visibility
- Check mirrors and windows for cracks, visibility, secure mounting and cleanliness.

- **Regular inspection for interior safety and other features:**
  - Inspect seats-cushions, secure fastening and passenger comfort
  - Check handholds, grab rails and seat belts (where provided)
  - Verify door opening and closing mechanisms for smooth and reliable operations. Also check the operations and functionality of emergency doors/ hatches/ glass breaking devices.
  - Ensure bus movement is permitted only when doors are fully closed
  - Inspect wheelchair accessibility ramps or lifts (where provided) for functionality, secure anchorage and safety alerts.
  - Check operations of audible and visual alerts related to safety systems.
  - Inspect interior cooling and ventilation systems, including air-conditioning (where provided), for proper performance.
- **Regular inspection of technological systems /ITS and related sub-systems:**
  - Verify the operational condition and effective utilisation of all onboard technological and Intelligent Transport Systems (ITS).
  - Test Advanced Driver Assistance Systems (ADAS) for proper calibration and performance.
  - Verify Driver Fatigue Monitoring Systems (DFMS) for alert accuracy and responsiveness.
  - Check the Battery Management System (BMS) for data accuracy, alerts, and fault reporting.
  - Verify real-time vehicle monitoring systems for continuous data transmission and system health.
  - Inspect onboard microprocessors and control units for fault codes, software integrity and reliable operations.

### *D. Monitoring*

Continuous real-time monitoring of battery and vehicle health is critical for ensuring safe and reliable operation of e-buses and for preventing failures such as thermal events and system malfunctions. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 11 Stakeholder-Specific Monitoring Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Enable Real time monitoring through BMS | Operator's Control Room Team |
| 2. | Monitor Battery Health | Operations/ Technical Team; OEM |
| 3. | Centralise Monitoring Data | Operator's & STU Control Room Team |
| 4. | Trigger Automated Alerts on driver's dashboard | Operator's Control Room Team; Depot & Central Workshop System |
| 5. | Manage Thermal Systems | Operator's Control Room Team; Depot & Central Workshop System |
| 6. | Strengthen BMS Capability | Operations/ Technical Team; OEM |
| 7. | Act on Early Warnings | OEM; Depot & Central Workshop System |
| 8. | Define Response Levels | Operator's Control Room Team; Depot & Central Workshop System |
| 9. | Implement Asset Management | Operations/ Technical Team; OEM |
| 10. | Update System Securely | OEM; ITS Team |

The following section outlines the recommended practices for Battery Management System (BMS) enabled monitoring, alert mechanisms and response protocols to enable early detection of anomalies, timely intervention, and effective risk mitigation across depot and central command operations.

- **Enable Real time monitoring through BMS:** Real time monitoring at a headway of 5-10 seconds is advised to be conducted to track key parameters indicated by the Battery Management System (BMS) and promptly detect any anomalies in the battery system.

- **Monitor Battery Health:** BMS monitoring enables tracking of temperatures, state of charge and other battery health indicators. Regular observations and analysis of these parameters, by the public bus transport agencies operations and technical team and by the OEM help in preventing potential battery malfunctions.

- **Centralise Monitoring Data:** The real time monitoring data is recommended to be sent to both at depot level control centre and central command centre.

- **Trigger Automated Alerts on driver's dashboard:** Alerts are advised to be automatically triggered when thresholds are breached and are communicated to relevant teams, with critical alerts displayed on the driver's dashboard.

- **Manage Thermal Systems:** Thermal management system attempts to manage the functioning of cooling/heating systems, temperature levels of various sub-systems to keep the battery and other systems at safe temperatures and to avoid thermal runaway reactions that can cause fires.

- **Strengthen BMS Capability:** Strengthen BMS to have exhaustive capabilities for real time temperature & voltage monitoring, cell imbalance detection, battery current and SoH & SoC tracking besides those normally provided.

- **Act on Early Warnings:** Take necessary corrective action on early warning triggers identified through telematics, BMS, thermal sensors, vibration sensor and other tell-tale signs, etc.

- **Define Response Levels:** The Operators Command & Control Centre and depot operations team is advised to continuously monitor for any emergency alerts indicating potential damage or faults in e-buses. Based on the severity of the alert, response actions may be categorized[25] as follows:
  - Level 1 – Immediate alert: Requires urgent attention; maintenance personnel, normally from DWS, are to visit the site immediately to inspect and rectify the fault preferably on site.
  - Level 2 – Same day response: The issues be addressed within the same day through inspection and necessary repairs normally at DWS.
  - Level 3 – Scheduled assistance: Non-critical issues be attended to within 2–3 days for inspection and corrective action – either at DWS or CWS basis nature of failure and the corrective action.

- **Implement Asset Management:** The operations/ technical team needs to implement an asset management system for regular monitoring and optimisation of the entire lifecycle and performance of the assets, including battery health amongst others as an integral component of overall safety and risk management framework.

- **Update System Securely:** In case of technological advancements, regularly update software and hardware[26] with manufacturer support to prevent data breaches that could compromise telematics and lead to data theft or misuse.

## *E. Capacity Building*

Capacity building of crew, operations and technical staff is critical to ensuring safe, efficient, and resilient operation of e-bus services. Structured training and upskilling programmes enable early detection of faults, effective emergency response, and compliance with operational and safety protocols. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 12 Stakeholder-Specific Capacity Building Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| **1.** | Train crew on bus operations | Capacity Building Team; Drivers - Conductors |
| **2.** | Identify defects early defects while the bus is enroute | Capacity Building Team; Drivers - Conductors |
| **3.** | Recognise Cyber threats | ITS Team; Drivers - Conductors |
| **4.** | Training of crew on Disaster Response Protocols | First Responders; Drivers - Conductors |

[25] Source: Internal Discussions with experts and Workshop Insights
[26] Technology Obsolescence – SAP LeanIX

| S.N. | Activities | Responsibility |
|---|---|---|
| 5. | Train Depot technicians and other staff | Capacity Building Team; Depot & Central Workshop System |
| 6. | Training on fire safety | Capacity Building Team; Drivers - Conductors |
| 7. | Conduct Mock Drills | First Responders; Drivers - Conductors |
| 8. | Adopt Blended Training | Capacity Building Team; Safety Officer |

**Fire responder- (Fire Brigade/ Police/ Ambulance)*

The key aspects of capacity building are brought out here-under:

- **Train crew on bus operations:** Train bus crew on overall functioning of e-buses, including familiarity with functioning of safety critical sub-systems, tell-tale signs, dashboard signs and controls, handling of safety equipment/ provisions on board and operational nuances.
- **Identify defects early while the bus is enroute:** Train crew, particularly drivers, to precisely recognise tell-tale signs for early detection of defects related to electrical systems, batteries, cooling systems, battery charging and discharging of levels, temperature levels in various sub-systems to facilitate timely corrective actions and avoid occurrence of any disaster.
- **Recognise Cyber Threats:** Educate crew, specifically drivers on understanding signs of cyber tampering (e.g., dashboard anomalies, unauthorized access attempts, on board microprocessor behaviour, etc).
- **Training of crew on Disaster Response protocols:** Train crew in disaster response, including safe evacuation of passengers, managing road users behaviour at incident sites, isolating defective buses, coordinating effectively with relevant agencies and safely securing the site and the vehicle.
- **Train Depot technicians and other staff:** Train depot staff, mainly technicians on battery construction, operations, maintenance, handling and storage protocols and monitoring of battery condition basis operating parameters obtained during the day, as well as routine servicing and repairs processes as also in handling emergencies in EBES caused mainly due to various disruptions.
- **Training on Fire Safety:** Bus crew and other depot staff be trained in recognition of fire signages, use of fire extinguishers, and the SOPs to handle fire caused emergencies.
- **Conduct Mock Drills:** Organise regular mock fire drills with bus crew, depot staff, and the first responders.
- **Adopt Blended Training:** Undertake combination of classroom instructions, e-learning and hands-on training in operation, defect identification and rectification processes of EBES, sub-systems and components to provide a comprehensive learning experience.

## 6.2. Component 2: Depot Infrastructure and Management

Optimal planning and design of depots/ terminals for e-buses are foundational to build a disaster-resilient EBES. It commences with identification of depot/ terminal sites for e-buses at strategic locations near power supply sources, accessible road networks, conforming land-use and away from areas vulnerable to flooding, fault lines, landslides or from coastal threats such as high wind velocity and storm surge. Depots and terminals are recommended to be in proximity to the bus routes for service optimisation. Careful site selection, whether upgrading existing depots/terminal for electrification or developing new greenfield facilities is essential to ensure seamless integrated depot design[27] to enhance energy efficiency, cost optimisation, electrical infrastructure and operational sustainability and disaster resilience.

In addition to meeting the requirements of a conventional bus depots/terminal for conventional buses, e-bus depot/terminals need to incorporate specialised infrastructure to ensure safety and resilience. Key provisions include high power charging systems, energy efficient layouts, robust fire safety systems, surveillance and access control, and clearly defined safety and emergency response protocols tailored to electric mobility.

Against this backdrop of evolving operational and safety requirements for electric bus systems, the rapid pace of urbanisation and the growing adoption of e-buses by public bus transport agencies[28] have further intensified the need for appropriate depot infrastructure. This transition has necessitated both the development of new purpose-built e-bus depots in expanding cities and the conversion of existing conventional bus depots to support electric operations, giving rise to distinct depot typologies that are categorised in following paragraphs.

- **Brownfield depots,** which involve the retrofitting or upgrading of existing bus depots to meet the electrical, spatial, safety, and operational requirements of e-bus systems.
- **Greenfield depots**, which are developed on undeveloped land and offer the opportunity to optimise depot design from the outset, including the layout of charging infrastructure, substations, maintenance bays, internal circulation, and renewable energy systems.

**Existing depot manuals and guidelines:**

In the Indian context, the MoHUA Manual for Planning, Design and Implementation of City Bus Depots (2020) provides valuable guidance on site selection, layout planning, internal workflows, and maintenance facilities. However, they are primarily tailored to conventional internal combustion engine (ICE) bus depots and offer limited direction on e-bus specific requirements[29].

To address certain operational aspects, CESL under the National Electric Bus Program has developed an SOP focused on upstream electrical infrastructure, including power demand estimation, grid connectivity, and coordination with DISCOMs; however, it does not comprehensively cover depot architecture, integrated energy planning, or long-term optimisation. Similarly, the India Smart Grid Forum (ISGF), a public–private partnership with the Government of India, has conducted a study identifying key electrical safety risks at EVSE-enabled bus depots, such as voltage sags, swells, harmonic distortions, and voltage fluctuations that can affect equipment safety and operations. While the study emphasises the need for continuous monitoring and proposes a draft SOP outlining electrical safety measures for EVSE deployment, it does not comprehensively address broader e-bus depot design, planning, architectural considerations, or long-term monitoring and maintenance aspects.

[27] Integrated depot design refers to a holistic planning approach in which all essential components required for e-bus operation such as parking, maintenance, charging infrastructure, energy supply systems, staff amenities, and internal traffic circulations are planned in a coordinated manner. This approach optimises land use, enhances operational efficiency, reduces long-term costs, and supports clean and sustainable transport systems.
[28] Public Bus Transport Agencies that manage public bus services in urban cities such as State Transport Undertaking (e.g. Karnataka State Road Transport Corporation), Municipal Transport Undertaking (e.g. Bengaluru Municipal Transport Corporation) and Special Purpose Vehicle (e.g. Sitilink, Surat).
29 Renewable Powered Electric Bus Depot Design and Strategies, 2025

This section on E-Bus Depot Infrastructure Planning bridges these gaps by presenting an integrated approach to safe and resilient depot operations, combining depot design, energy-efficient planning, renewable energy integration, and safety and resilience considerations. It complements existing guidelines while addressing the practical design and operational requirements of both brownfield and greenfield e-bus depots in India.

**E-bus Depot Layout:**

The e-bus depot layout is advised to be designed for efficient e-bus parking-preferably compartmentalised in lots of 24-25 buses in case of a 100 standard size buses depot but must be customized to meet local circumstances and safety issues. Sufficient separation space (of the order of 4-5 meters)[30] between compartments and provision of fire screens for each compartment is recommended to prevent spread of fire in one lot to other lots. This would facilitate uninterrupted operations though marginally curtailed.

The other facilities that are not specific to e-buses such as repair, maintenance, administrative blocks, security, driver rest zones, training rooms, parking of staff vehicles, storage and waste disposal can follow the same standards and layouts used for a conventional bus depots. Additional facilities required for e-buses include dedicated zones for charging infrastructure, safe handling and storage of damaged e-buses including those involved even in minor collisions, storage and disposal of end-of-life batteries and other components. Additional space may also be required for the DISCOM for creating a sub-station and installation of step-down transformers for requisite power supply to the charging station. Overall, the civil infrastructure is suggested to be climate-resilient, structurally sound, and scalable to accommodate future fleet expansion. Collectively, these design principles aim to create safe, resilient, and efficient depot environment that supports the long-term sustainability, safety, and reliability of the EBES. E-bus terminals may include provision for opportunity charging and overnight parking in alignment with the fire, electrical & water protection safety measures similar to those identified for the e-bus depots.

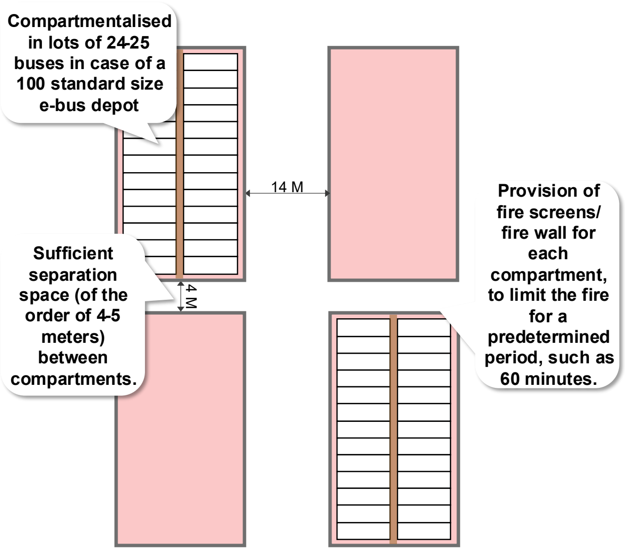



*Exhibit 66 Part E-Bus Parking Layout in an E-Bus Depot*

These principles are elaborated in the following section. The stakeholder roles mapped out below can help ensure that both new and existing depots are future-ready, energy-efficient, and aligned with India's sustainability and urban mobility objectives.

## A. Planning & Design Recommendations

This section outlines a comprehensive safety and resilience framework for **planning, designing, and operating e-bus depots and terminals.** It integrates electrical, thermal, water, cyber, structural, and occupational safety considerations. The recommendations apply to both greenfield

[30] A Review of Safety Measures in Battery Electric Buses, MDPI

and brownfield depots and emphasise hazard prevention through site planning, engineering controls, standard operating procedures, and workforce preparedness.

These mitigation measures aim to enhance depot safety, asset protection, service continuity, and long-term sustainability of e-bus operations. Detailed planning and standard recommendations are presented in the respective sections.

## I. Electrical Safety

### *Planning Recommendations*

*Table 13 Stakeholder-Specific Electrical Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **ELECTRICAL SAFETY** | | |
| **1.** | Prioritise Grid Proximity | Civil/ Electrical Department; Planning Team |
| **2.** | Avoid Overhead Lines | Civil/ Electrical Department; Planning Team |
| **3.** | Safely Locate Transformer and Substations | Civil/ Electrical Department; Planning Team |
| **4.** | Provide Power Redundancy | Civil/ Electrical Department; Planning Team |
| **5.** | Establish safe boundaries to minimise risk of electrical injuries | Civil/ Electrical Department; Depot & Central Workshop System |

- **Prioritise Grid Proximity:** For both **brownfield and greenfield e-bus depot / terminals**, prioritise the site near an **existing high-voltage infrastructure** / grids, that has adequate capacity to cater to the requirement of existing fleet as well future expansions and upgrades of the e-bus depot/ terminal.
- **Avoid Overhead Lines:** During site selection, ensure that **no high-tension towers or overhead cables pass** over or through the depot/ terminal premises to minimise safety risks.
- **Safely Locate Transformer and Substations:** Locate the transformer and the substations in designated safe area in compliance with applicable regulations. Layout should account for transformer's capacity, safety clearance, cable trenching routes and contingency provisioning (e.g. dual feed)[31].
- **Provide Power Redundancy:** Create redundancy by way of providing **duplicate or separate electricity cables** to ensure at least half of the fleet remaining operational during disruptions.
- **Establish safe boundaries to minimise risk of electrical injuries:** Clearly defined safety boundaries shall be established around electrical equipment (such as Compact Sub Station, Switchgear, Ring Main Unit, Transformer, charger power cabinets, etc) to physically and procedurally separate personnel from electrical hazards during both normal operation and maintenance. To address these risks, NFPA 70E and IEEE 1584 define three critical electrical safety boundaries as follows:

31 Renewable Powered Electric Bus Depot Design and Strategies

- **Restricted Approach Boundary:** Allows only qualified personnel with insulated tools and PPE. This boundary may be clearly demarcated using red floor markings or painted zones.
- **Limited Approach Boundary:** Prevents unqualified personnel from entering zones near energized parts. This boundary may be clearly demarcated using yellow floor markings or painted zones.
- **Arc-Flash Boundary:** Defines the distance at which arc-flash energy can cause second-degree burns, requiring full arc-rated PPE. This boundary may be clearly demarcated using orange or dashed line floor markings or painted zones.


*Exhibit 67 Risk Zoning in E-Bus Depot to minimise risk of electrical injuries*

***Design Standards***

The following standards shall be incorporated in the planning and design of e-bus depot and terminal by the Civil and Electrical Engineering team of the public bus transport agencies, with involvement of OEMs wherever they are part of the e-bus depot planning and design process.

- **High-voltage and fire safety systems** should include battery isolation units, high-tension earthing grids, temperature and smoke detection sensors designed in accordance with NBC 2016 and IEC 60364.
- Design layout is recommended to:
  - Clearly **segregate High-Voltage (HV) and Low-Voltage (LV) panels**
  - Ensure **unobstructed access paths** to isolation switches and control panels
  - Utilize **fire-retardant cable trays** and **armoured High Voltage cables** for fire and arc flash safety

**RECOMMENDED STANDARDS**

*All Electrical Infrastructure in E-Bus Depot/ Terminal must comply:*

- *Code of practice for Earthing: IS3043*
- *Electrical Installation in building: IS732/ IEC 60634*
- *Guide for Performing Arc Flash Hazard Calculations: IEEE 1584*
- *IP 54+ Protection: For all indoor electrical panels/ switchgear*

- All depot/ terminal **switchgear and control panels** are recommended to:
  - Use arc-rated switchgear with internal arc containment as per IEEE 1584 guidelines
  - Have **IP54 or higher-rated enclosures** for indoor panels to ensure dust and moisture protection
- Include type-tested LT/HT panels with **interlocks for operator safety & Visual indicators** for circuit status (ON/OFF/Trip)
- Clearly **label Circuit identification**; Hazard signage (e.g., "Danger – 415V" or "Arc Flash Risk")

## II. Thermal Safety

### *Planning Recommendations*

*Table 14 Stakeholder-Specific Thermal Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **THERMAL SAFETY** | | |
| 1. | Compartmentalise E-Bus Parking | Civil/ Electrical Department |
| 2. | Fire Risk Zoning in depots | Civil/ Electrical Department, OEM |
| 3. | Early Detection, Suppression & Firewater Management: | Civil/ Electrical Department |
| 4. | Provide for Battery Storage | Civil/ Electrical Department |
| 5. | Use Fire Retardants Materials | Civil/ Electrical Department |
| 6. | Limit Toxic Materials | Civil/ Electrical Department |
| 7. | Maintain Repair zone Cleanliness | Civil/ Electrical Department, OEM |
| 8. | Ensure adequate and safe ventilation | Civil/ Electrical Department |
| 9. | Restrict Repair zone Access | OEM, Depot & Central Workshop System |
| 10. | Control Dust Levels | Civil/ Electrical Department, OEM |
| 11. | Provide Shading | Civil/ Electrical Department |
| 12. | Application of Cool Roof Treatment: | Civil/ Electrical Department |

- **Compartmentalise E-Bus Parking:** Provide compartmentalisation for parking of e-buses along with fire-barriers or fire-safe curtains[32] and designated quarantines zones to effectively mitigate fire risks and minimise disruption in operations.

32 7 Battery Electric Bus Fire Mitigation Strategies, GfTinc

- **Fire Risk Zoning in Depots:** All depots while planning or in the existing construction shall be reclassified into fire risk zones to minimise safety risks.
    - High-risk zones: charging bays, substations, transformers
    - Moderate-risk zones: workshops, maintenance bays
    - Low risk / safe occupancy zones: offices, control rooms, staff facilities
- **Early Detection, Suppression & Firewater Management:** The early detection system (Heat, smoke) is only present in admin building. The early detection and suppression system can be further improved using following measures:
    - **Thermal Imaging:** Infrared & thermal imaging helps in detecting hotspots & anomalies in battery temperature.
    - **Arc Fault Detection Device:** Detect dangerous electrical arcs caused by loose connections or damaged cables, and electrical fires.
    - **Surge Protection Devices (SPD):** SPDs protect chargers and electrical systems from voltage spikes due to lightning, grid fluctuations, or switching surges. They prevent damage to sensitive power electronics, reduce downtime, and improve overall system reliability.
    - **Firewater drainage shall be reviewed to ensure:** No backflow into electrical rooms and no pooling near chargers or substations
- **Provide for Battery Storage:** A dedicated and secure space, preferably segregated from parked e-buses, staff areas, and other core depot facilities, should be provided for battery storage, given the significant fire, explosion, and chemical hazards associated with batteries.
- **Use Fire Retardants Materials:** Use materials with a fire-retardant coating wherever deemed necessary.
- **Limit Toxic Materials:** Limit the amount of toxic and hot gases generating materials in an e-bus depots/ terminals.
- **Maintain Repair zone Cleanliness:** Maintain high voltage power battery repair sites clean, dry, spark free and free of greases, stains and metal debris. Avoid locating the repair zones near vehicle cleaning area and use movable partition if necessary.
- **Ensure adequate and safe ventilation:** Ensure adequate ventilation (indoor) or open-air setting (outdoor), with clear signage prohibiting fire, water and high-voltage hazards.
- **Restrict Repair zone Access:** Allow access to authorized repair personnel only.
- **Control Dust Levels:** Apply dust control treatment on floors or other surfaces to extend equipment life and reduce arc flash risk.
- **Provide Shading:** Use **shading (trees or canopy structure)** to mitigate the heat stress and maintain microclimate.
- **Application of Cool Roof Treatment:** Apply cool roof treatments or shading devices to minimise direct solar heat exposure on the depot roof and charging infrastructure shed/ canopy thereby reducing overall heat buildup.

***Design Standards***

The following standards shall be incorporated in the planning and design of e-bus depot and terminal by the Civil and Electrical Engineering team of the public bus transport agencies, with involvement of OEMs wherever they are part of the e-bus depot planning and design process.

**RECOMMENDED STANDARDS**

- *Fire Safety Guidelines: NBC 2016: Part IV for fire protection and relevant local byelaws, ISI codes such as IS15105:2002, IS:5290, IS:5312. IS:908 and IS:2190.*
- *Fire Detection and Alarm System: IS 2189:2008 for the design and installation of FDAS and NFPA 72 (International Code) on fire alarm and signalling.*
- *Installation of Sprinkler System: NFPA 13 (International Code)*
- *CEN and Standards Australia governing the design, installation, and maintenance of water mist fire protection system.*

- E-bus parking areas be **compartmentalized with fire protect barriers** to reduce the risk of fire spread. For example, in a depot with 100 e-buses, the parking layout be divided into four zones compartments each accommodating 25 e-buses. The layout may be customised to meet local circumstances and safety issues[33].
- A **minimum 4m gap** is advisable between compartments to allow access for fire trucks during emergencies[34].
- Install **high-pressure water mist system** as a firefighting system at e-bus depot/ terminal to help reduce the intensity of thermal radiation from flames to the surroundings[17].
- **Fire risk mitigation design** is recommended to account for ventilation effects, as they impact suppression zones, water storage volumes, and potential delay in fire control that may increase losses.
- **Install infrared and thermal imaging technologies** that are effective in detecting battery hotspots and temperature anomalies. When integrated with **building automation systems**, they enable real-time monitoring and early detection of potential fire risks[35].
- The most significant risk related to working with e-buses is **"arc flash" and "thermal runaway"** which underlines the clear need to design out some risks and create standard operating procedures (SOPs).
- Establish guidelines on **fire safety and evacuation** along with clearly defined emergency routes, and designated refuge areas within depots/ terminal premises.

[33] A Review of Safety Measures in Battery Electric Buses, MDPI
[34] A Review of Safety Measures in Battery Electric Buses, MDPI
[35] Battery Electric Bus Fire Mitigation Strategies

## III. Water Protection

### *Planning Recommendations*

*Table 15 Stakeholder-Specific Water Protection Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **WATER PROTECTION** | | |
| **1.** | Avoid Sensitive Land Use | Civil/ Electrical Department, Planning Team |
| **2.** | Access Flood Hazards | Civil/ Electrical Department |
| **3.** | Mitigating Low-Lying Risk | Civil/ Electrical Department |
| **4.** | Design Surface Drainage | Civil/ Electrical Department |
| **5.** | Implement Detention Measures | Civil/ Electrical Department |
| **6.** | Provide Emergency Dewatering System | Civil/ Electrical Department |
| **7.** | Build Flood-Resilient Structure | Civil/ Electrical Department, OEM |

- **Avoid Sensitive Land Use:** Avoid depot site location in close proximity to residential areas and other non-conforming land uses for depot activities.
- **Access Flood Hazards:** Conduct hydrological studies based on a 1 in 100 years return period or assess flood hazards[36].
- **Mitigating Low-Lying Risk:** If the yard level of a depot/ terminal is lower than the surrounding roads or land, it faces a high risk of flooding which may pose significant risk due to presence of electrical infrastructure. Following measures are recommended to avoid such vulnerabilities:
    - If the **brownfield depot/ terminal** is in low- lying as above or located in **flood prone areas**, then raise the depot/ terminal ground level to at least the flood safety heights.
    - For **greenfield e-bus depot/ terminal**, select the site above historical flood levels, avoid locating the depot site in low-lying or floodplain zones.
- **Design Surface Drainage:** Conduct a **detailed contour survey** to design proper grading and slope for surface drainage. Ensure that the location of any new depot/ terminal is not near a steep hill or in a flood prone area. Provision of waterproofing membranes, and underground drainage systems to prevent water accumulation are also recommended.
- **Implement Detention Measures:** Construct micro-detention reservoirs, rainwater harvesting pits and install porous pavements to prevent water coming inside the depot.
- **Provide Emergency Dewatering System:** Depots/ terminal advised to be equipped with water pumps and sandbags to prevent water accumulation and enable quick drainage.
- **Build Flood-Resilient Structure:** Design and construct flood-resilient battery storage areas, charging bays, and electrical rooms based on regional flood maps and hydrological assessment.

[36] BMPTC Vulnerability Atlas of Inda – Flood Hazards

### *Design Standards*

The following standards shall be incorporated in the planning and design of e-bus depot and terminal by the Civil and Electrical Engineering team of the public bus transport agencies, with involvement of OEMs wherever they are part of the e-bus depot planning and design process.

- Maintain the **plinth level** of the depot/ terminal and charging infrastructure **at least 0.5 to 1.0 meter above the highest recorded flood level (HFL)**. Alternatively, charging infrastructure may be installed on moveable platforms that can be adjustable as required.
- Storm water and drainage:
  - Provide stormwater drains or RCC open channels along driveways.
  - Include **grated trench drains** at vehicle entry/exit points.
  - **Ensure optimal drainage, of minimum 1%-2%**[37] for hardscapes (bus driveways) to natural drainage points.

**RECOMMENDED STANDARDS**

- ***Integrate auto cut-off systems to isolate power in case of water intrusion****: AIS-138 Part 2, Clause 7.0.*

- Incorporate **emergency evacuation lanes and designated flood-safe parking zones** within the of e-bus depot/ terminal design. In case of emergency, Asset evacuation SoP is to be activated upon early warning alerts from IMD or local authorities.
- Install **flood resilience measures** such as pumps, rainwater harvesting structure, underground drainage pipes to drain out excess runoff in the depot area.
- Install **moisture sensors, water alarms, and water level indicators** near critical electrical and mechanical zones.
- Equip depots with **sump pumps, water diversion channels, and emergency diesel pump systems** to rapidly drain water from electrical areas.
- Store **maintenance equipment, PPEs, and battery tools in elevated** waterproof storage units.

## IV. Cyber Security

### *Planning Recommendations*

*Table 16 Stakeholder-Specific Cyber Security Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **CYBER SECURITY** | | |
| **1.** | Develop Cybersecurity Protocols | OEM, ITS Team |
| **2.** | Secure Grid Communication | OEM, ITS Team |
| **3.** | Train Depot Personnel | OEM, ITS Team |

[37] Manual of storm Water drainage System – MoHUA, 2019

| S.N. | Activities | Responsibility |
|---|---|---|
| 4. | Restrict Zone Access | OEM Depot & Central Workshop System |
| 5. | Update Software Regularly | OEM |
| 6. | Implement Backup Systems | OEM |
| 7. | Enforce Access Controls | OEM |
| 8. | Maintain Security Scanning | OEM |

- **Develop Cybersecurity Protocols:** Establish depot/ terminal specific cybersecurity protocols.
- **Secure Grid Communication:** Use Open Automated demand response (OpenADR) with encrypted communication for grid interaction.
- **Train Depot Personnel:** Train depot/ terminal personnel on cyber hygiene, cyber security and incident response.
- **Restrict Zone Access:** Restrict access to critical zones within the depot/ terminal.
- **Update Software Regularly:** Ensure all software systems are updated at defined intervals.
- **Implement Backup Systems:** Implement robust backup systems for critical depot/ terminal operations to ensure continuity during cyber incidents or system failure.
- **Enforce Access Controls:** Maintain strong password and multifactor authentication for important depot/ terminal access.
- **Maintain Security Scanning:** Maintain latest scanning software with preset scanning frequency for stored data and pre-entry scanning of all incoming data.

## V. Structural Safety

### *Planning Recommendations*

*Table 17 Stakeholder-Specific Structural Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **STRUCTURAL SAFETY** | | |
| 1. | Designated Earthquake Zones | Civil/ Electrical Department |
| 2. | Seismic Wind Design | Civil/ Electrical Department |
| 3. | Anchor Against Debris | Civil/ Electrical Department |
| 4. | Provide Reinforced Shelters | Civil/ Electrical Department |
| 5. | Enhance Pedestrian Safety within E-Bus Depot | Civil/ Electrical Department |

**RC- Reconditioning unit; Fire responder- (Fire Brigade/ Police/ Ambulance)*

- **Designated Earthquake Zones:** While planning the site, earmark designated open area as an earthquake-safe zone, allowing staff and crew to evacuate safely in the event of high seismic activity. Provide and clearly mark earth-quake safe spaces inside all buildings of the depot/ terminal to enable safe positioning of staff in the event of evacuation time being too short.
- **Seismic Wind Design:** Design depots/ terminal and charging stations to withstand high wind speeds and minor seismic activity.
- **Anchor Against Debris:** Use wind-anchored enclosures and protective systems to resist flying debris during high-wind or storm events.
- **Provide Reinforced Shelters:** Provide indoor or sheltered charging station with bus ends up to charging ports with reinforced canopies and anchor systems.
- **Enhance Pedestrian Safety within E-Bus Depot:** As e-buses generate significantly lower noise levels than ICE vehicles, provide clearly marked pedestrian zones within the e-bus depot with all-weather visibility, physically separated from driving lanes, high-voltage zones, and areas requiring personal protective equipment, to reduce collision risks.

***Design Standards***

The following standards shall be incorporated in the planning and design of e-bus depot and terminal by the Civil and Electrical Engineering team of the public bus transport agencies, with involvement of OEMs wherever they are part of the e-bus depot planning and design process.

- Leverage existing **building bye laws** and recommended practices on earthquake and cyclone resistance while designing greenfield depots/ terminals for e-buses, ensuring better preparedness and sustainability.
- **Bus parking and movement:**
  - Design bus parking with elevated hardstands and reverse-slope-free entries.
  - Use reflective markings and signage to guide buses during low visibility.
  - Charger Layout[38]: Charger pedestals may follow the design standard (1 m × 1 m, 450-600 mm height) with at least 1 m clearance on all sides. Maintain 1.5–2 m distance from walls, and 1.0–1.5 m between adjacent chargers. Refer to the illustrations for visual guidance on these dimensions.
  - Minimum space width for parking a 2.6 m wide bus be 3.6 m and that for charging an e-bus may be 4.6mtrs.
  - A 45-degree parking layout with over 12m turning radius allows easy manoeuvring for standard sized buses.
  - Maintain a minimum clearance of 2 meters space between the bus and the charging infrastructure while parking an e-bus for charging.

[38] Source: Internal Discussions with experts and Workshop Insights

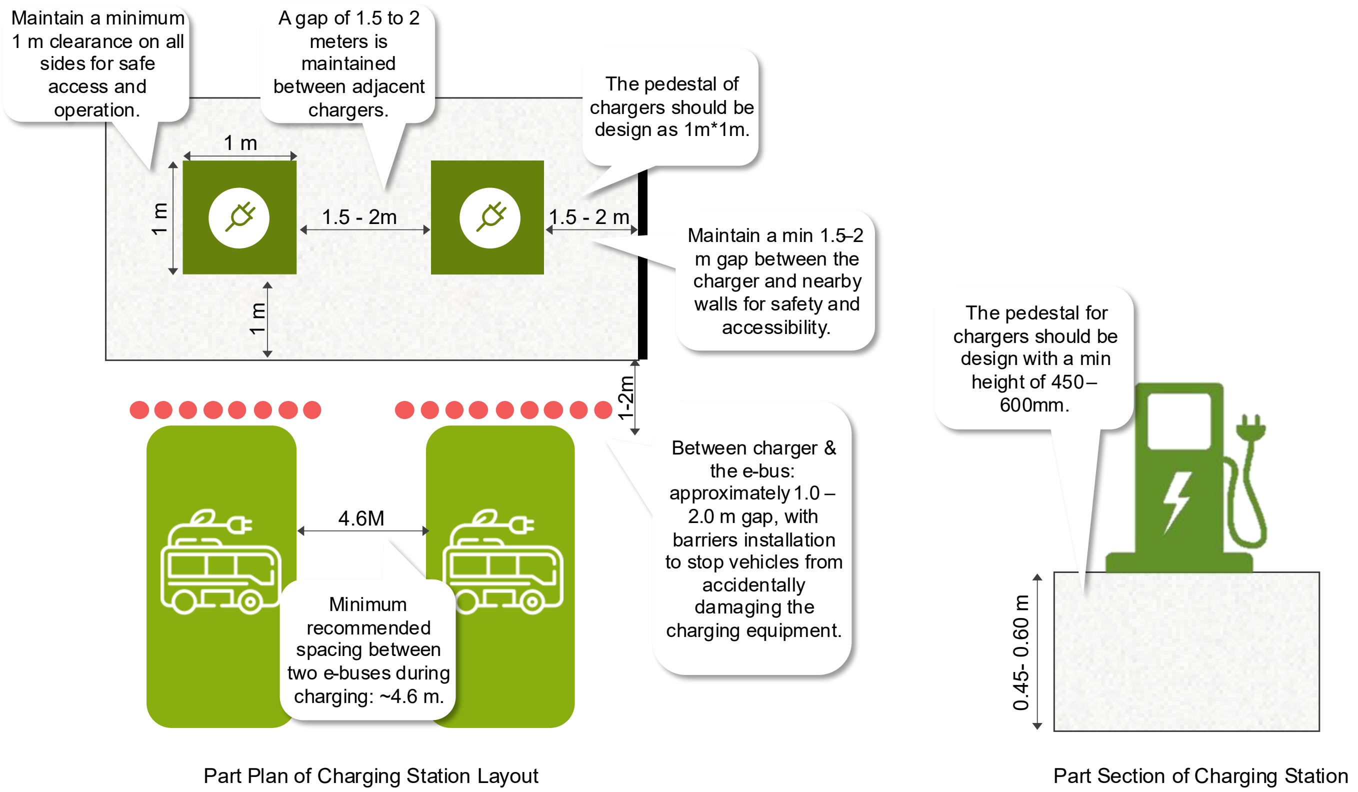



*Exhibit 68 Illustration of a typical Charging Layout in an E-Bus Depot/ Terminal (*Not to Scale)*

- Install **floor-level stopping guides** to help drivers align accurately to designated space and to prevent collision between e-buses and charging infrastructure.
- Implement real-time **CCTV surveillance within the depot/ terminal** and at other key locations.
- **Restrict entry** via biometric access, ID badging, and automated gates during high-risk periods.
- Install **guided parking systems** and protective infrastructure in high-risk parking zones.
- Use **color-coded curbing for safe navigation**.
- **Reduce speed limits within depot premises** may be introduced using geofencing and onboard speed limiters.

## VI. General Safety Measures

*Table 18 Stakeholder-Specific General Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **GENERAL SAFETY MEASURES** | | |
| **1.** | Optimise Depot Layout | Civil/ Electrical Department |
| **2.** | Entry-Exit to the depot | Civil/ Electrical Department; OEM |
| **3.** | Account for additional infrastructure space | Civil/ Electrical Department |

| S.N. | Activities | Responsibility |
|---|---|---|
| 4. | Plan Compact Infrastructure | Civil/ Electrical Department |
| 5. | Conduct Risk Assessment | Civil/ Electrical Department |
| 6. | Ensure Route Proximity | Civil/ Electrical Department Planning Team |
| 7. | Zone Depot Areas | Civil/ Electrical Department OEM |
| 8. | Accessible Shutdown Buttons | Civil/ Electrical Department OEM |
| 9. | Provide Quarantine Space | Civil/ Electrical Department |
| 10. | Allocate Charging Space | Civil/ Electrical Department OEM |
| 11. | Prevent Obsolescence Risks | OEM |
| 12. | Approval and Sanctions Required | Civil/ Electrical Department Planning Team |
| 13. | Plug Based / Pantograph Charging System at Depot | Civil/ Electrical Department OEM |
| 14. | Manpower Safety Protection | OEM Depot & Central Workshop System |
| 15. | Occupational Safety | OEM Depot & Central Workshop System |
| 16. | E-bus washing area | Civil/ Electrical Department OEM |
| 17. | Repair and Maintenance area | Civil/ Electrical Department OEM |
| 18. | Quarantine area for Damaged buses / Equipment | Civil/ Electrical Department OEM |
| 19. | Battery Storage rooms | Civil/ Electrical Department OEM |
| 20. | Safety Procedures at Maintenance area | OEM Depot & Central Workshop System |
| 21. | Waste and Battery Management | Civil/ Electrical Department OEM |

** Fire responder- (Fire Brigade/ Police/ Ambulance)*

### *Planning Recommendations*

- **Optimise Depot Layout:** Create depot/ terminal layout plan to facilitate friction-free bus movements during entry-exit for parking of e-buses, workshops for repairs and the charging infrastructure for charging preventing congestion during peak hours.
- **Entry-Exit to the depot:**
    - Plan sperate entry and exit gates to aid **unidirectional movement** of buses that can streamline the movement friction free.

- Locate entry-exit gates in a manner that **minimises traffic disturbance outside the depot**.
- Install outdoor day/night **CCTV cameras with IP 65 protection**, along with perimeter access controls, and adequate lighting systems to enhance physical security and ensure uninterrupted operations, especially in depots with 24x7 fleet movements.

- **Account for additional infrastructure space:** E-bus depot requires more space to accommodate additional infrastructure such as **cabling, chargers, and transformer.** Provide additional depot space or reduce the capacity of the depot while converting an existing ICE buses depot to e-buses depot.
- **Plan Compact Infrastructure:** In space-constrained depots, efficient layout planning besides compact infrastructure provision are essential to minimize impacts, though fleet size reduction or relocation of part of the fleet will still be necessary.
- **Conduct Risk Assessment:** Undertake a detailed risk assessment for both brownfield and greenfield depots to identify and mitigate site-specific operational and safety risks.
- **Ensure Route Proximity:** For **greenfield e-bus depot**, ensure **proximity to bus routes and access** via well paved roads with a minimum **15m right of way** at entrance and exists, as per the MoHUA guidelines "Manual for planning, design & implementation of city bus depot, 2020", to reduce long term maintenance issues.
- **Zone Depot Areas:** Divide the depot into functional zones (such as high-risk zones, safe parking zones, and maintenance zones) to enable targeted disaster risk management and operational control.
- **Accessible Shutdown Buttons:** Locate all the emergency shutdown button at easily accessible locations.
- **Provide Quarantine Space:** Plan for provision of segregated space to park / quarantine e-buses involved in collisions and or in thermal runaways. Provide at least 2-4 meters space between quarantined buses and preferably with intervening fire screens.
- **Allocate Charging Space:** Provide for adequate space for charging station based on the number of chargers planned, including required clearances between buses and charging infrastructure. Additional space should also be allocated for power supply substations and transformers, with provision for future scalability to accommodate additional chargers or system upgrades as the fleet expands.
- **Prevent Obsolescence Risks:** To safeguard against technological obsolescence, depot management and technology controller are advised to update of software and relevant hardware periodically and maintaining vendor agreement for continued support.

***Approval and Sanctions Required***

Approval and sanctions required for both brownfield depot and greenfield depot are as follows:

- **Strengthen Approval Process:** The current e-bus depot approval process is followed for conventional bus depot norms and lacks EV-specific safety measures, hazard risks, and disaster resilience considerations. Obtain necessary additional approvals from agencies such as the Fire Fighting Department, DISCOMs, Disaster Management Authorities, Explosives Department and Electrical Inspectorates to address fire safety, chemical spillage and explosions from traction batteries, high-voltage electricity related risks, hazard zoning, and emergency preparedness etc. Integrating these clearances will ensure safer, more resilient depot operations.

- **Ensure Regulatory Compliance:** All required clearances should comply with applicable electrical regulations including the National Electrical Code (NEC) and International Electrochemical Commission (IEC) standards, as well as relevant fire safety codes, such as those issued by National Fire Protection Association (NFPA) and European Standard (EN) 50620 for EV infrastructure or any other relevant and accepted codes by the authority.
- **Mandate Design Audit:** In addition to the above approvals when converting a brownfield depot into an e-bus depot or constructing a new green field facility, the layout is recommended to undergo a third-party design audit[39] overseen by the Civil & Infrastructure department of the STU/ ULB during construction of the depot/ terminal.
- **Conduct Safety Audits:** A designated safety officer is advised to ensure annual third-party safety audits[40] of the e-bus depot or terminal to verify continued compliance, identify emerging risks, and strengthen overall safety performance.

***Plug Based / Pantograph Charging System at Depot***

- **Canopy charging system (plug-in or pantograph):** Built into overhead roofs are space efficient, minimises civil works and are suitable for flood prone areas as well.
- **Automated Overhead Charging:** The charging Infrastructure is installed at a height, and the charging takes place automatically. Thus, a revised parking bay to maximise the existing surface for the buses.

***Manpower Safety Protection***

- **Authorised Trained Technicians:** Only trained and certified technicians can perform maintenance on high-voltage components, systems
- **Buddy System Requirement:** Workers should never work alone on or near high-voltage systems. A colleague with equal or higher level training should be present.
- **Mandatory PPE Usage:** All personnel are required to use appropriate PPE specifically rated for the high-voltage levels present.
    - Insulated gloves: Use rubber gloves with the correct voltage rating.
    - Face shield: Protect against arc flash hazards.
    - Safety helmet: For head protection.
    - Electrical safety shoes: Rated for electrical hazards.
    - Flame-resistant (FR) clothing: Minimises burn injuries.

*Exhibit 69 Appropriate personnel safety gear while working on High-Voltage Equipment*

[39] Source: Internal Discussions with Experts & International Practices
[40] Source: Internal Discussions with Experts & International Practices

- **Non-conductive barriers:** Use rubber insulation mats and other insulated barriers to protect against electrical contact.
- **Decommissioning Procedure:** Before any maintenance or service work begins, a strict decommissioning procedure to be followed from preventing serious injuries or death[41].
    - **Isolate the vehicle:** Ensure the e-bus is not connected to the charging cable.
    - **Turn off ignition:** Switch off the vehicle's ignition.
    - **Perform lockout/tagout:** Implement lockout/tagout procedures to prevent accidental re-energization.
    - **Disconnect auxiliary battery:** Disconnect the 12V or 24V auxiliary battery and insulate the terminals.
    - **Remove the service plug:** Use the manual service disconnect, often a plug or switch, to break the circuit within the main HV battery pack.
    - **Discharge the system:** Wait for the time specified by the manufacturer (often 10 minutes) for the system to safely discharge. The vehicle's internal systems may automatically discharge to a safe voltage level below 60V DC.
    - **Verify zero voltage:** Before touching any HV components, use a rated voltage detector to confirm that the system is at zero potential (0V). Test the detector on a known live source first to ensure it is working correctly.
    - **Ground the work area:** For additional protection against accidental re-energising, grounds should be placed on both sides of the work area.

***Occupational Safety***

- **Defined Responsibility for Safety Protocols:** Fix responsibility for adhering to safety protocols, during operations, maintenance, cleaning of buses and the charging process using charging infrastructure, on the depot/ terminal staff, charging infrastructure staff and the bus crew.
- **Emergency power isolation:** In the event of electrical hazards or loss of control, the **immediately isolated and shut off of power source is recommended**. Install emergency shutdown mechanisms at high-risk areas, such as near transformers and inspection or repair stations.
- **Inclusive emergency alerting:** It is essential to ensure that all depot staff, including individuals with disabilities, are promptly alerted during emergencies. To enhance accessibility, install various alerting systems such as **non-auditory alarms like flashing beacons,** which provide visual or sensory alerts for persons with disabilities[42].
- **Heatwave worker protection:** During heatwaves provide shaded rest zones, hydration stations and regular breaks, along with installing industrial fans or evaporative coolers in workspace.

[41] Safe Handling of High Voltage Electrical Components in Electrical End of Life Vehicles
[42] Accessibility Guidelines for Bus Terminals and Bus Stops

- **Occupational safety standards:** Additionally, follow British Standards, OHSAS 18001:2007 (Occupational Health and Safety Assessment Standard) as reference standards to ensure overall health and safety of depot staff.

***E-Bus maintenance:***

- **E-bus washing area:**
    - Avoid using direct water spray, hoses or pressure washes on electrical compartments and components. Clean connector points with a dry cloth to remove dirt.
    - Develop SOP for e-bus washing to guide staff on safe practices and minimise human error or accidental exposure to electrical components.
    - Physical barriers, designated pathways, or clearly marked zones between washing and charging areas in an e-bus depot help prevent water or cleaning agent from damaging the charging equipment or creating safety hazards.
    - Ensure that high voltage components of e-buses are provided with ingress protection degree IP 65 or higher.
- **Repair and Maintenance area:**
    - Equip engineering bays with smaller or lower-power charging points to maintain vehicle battery levels during repair and maintenance activities.
    - Ensure that all charging infrastructure is serviced and maintained only by certified electricians who are trained and qualified to handle high-voltage equipment.
- **Quarantine area for Damaged buses / Equipment:**
    - In case of a damaged e-bus or electric vehicle supply equipment (EVSE), a physically separated room or enclosed area with firewalls be provided. This segregation is essential to minimize the risk of battery fires or thermal runaway incidents.
    - In case of scarce spaces, install firewalls or other features between the damaged buses.
- **Battery Storage rooms:**
    - The battery storage room is recommended to have humidity control, temperature control and adequate ventilation. Additionally, the whole building is required to be fire resistant /proof and should have a structural isolation.
    - Equip battery storage spaces in the depot with fire suppression systems and train staff to respond to fire emergencies and to adhere to battery-specific safety protocols.
    - Provide storage space for new battery packs depending upon frequency of replacement of retired battery packs and the cycle time to acquire new batteries e.g. a stock of 4-5 battery packs per 40 e-buses[43] be retained in the depot and an additional space for storge of unserviceable battery packs or retired battery packs be assessed and additional space to be provided for in design of depot.

[43] Source: Internal Discussions with experts and Workshop Insights

- The OEM to undertake disposal of EV batteries[44]. The OEM/ Operator to immediately evacuate damaged batteries from premises and retired batteries shall be collected within a week.
- The space is advised to be adequately ventilated, with batteries stored away from moisture and excessive heat, and in compliance with the design standards specified by the battery supplier.
- As per "Manual for Planning, Design and Implementation of City Bus Depots" notified by MoHUA, 15-30 air changes per hour are required for a high fume area such as battery room to prevent the room from overheating.
- A Category E fire alarm system be installed to address electrical fire risks common in industrial and commercial settings. This requires specialized detection and suppression systems, such as linear heat sensing cables, smoke detectors, fire detection and suppression systems (FDSS) and other specialised detection and suppression system for electrical hazards.

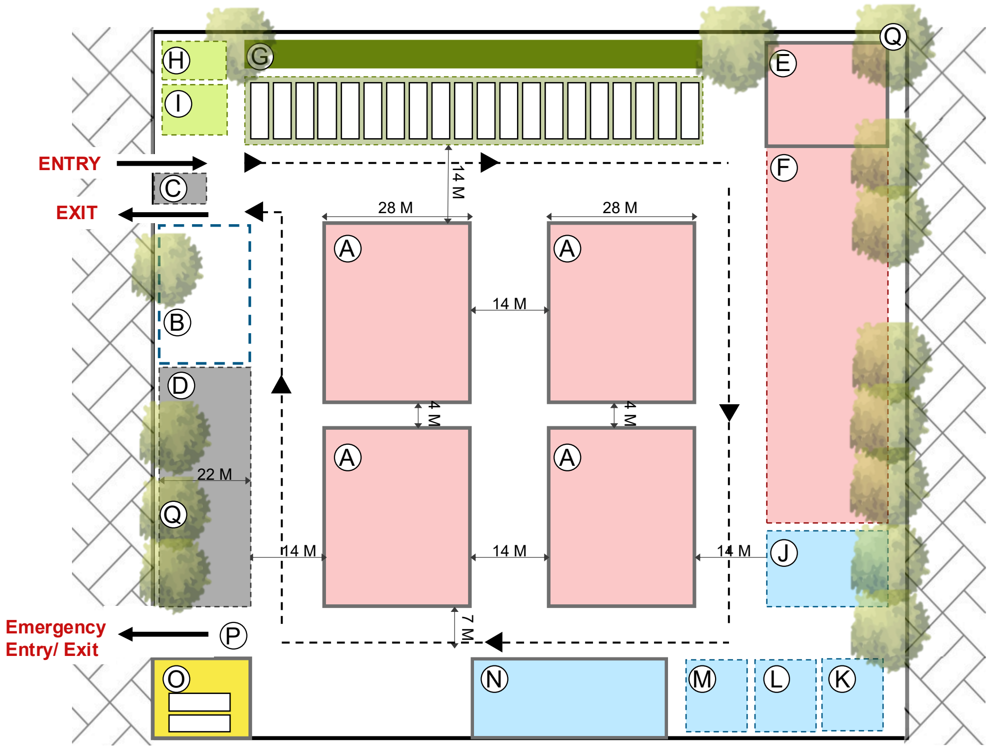
- **Safety Procedures at Maintenance area:**
  - All electrical and battery - related maintenance be carried out by specialised, trained and certified staff.
  - Staff performing electrical maintenance activities is required to wear appropriate PPE, including insulating gloves and protective screens.
  - Train engineering teams on the safe handling and isolation of high-voltage systems. Develop and implement a clear SOP for safety procedures, including emergency response protocols.
  - Re-train drivers to adapt to e-buses, focussing on safety and energy efficient driving techniques particularly related to acceleration and braking. As part of the highlight the fact that regenerative braking reduces brake pad wear and improves energy efficiency.
- **Waste and Battery Management:**
  - Designation of battery recycling zones and secure storage for spent lithium-ion batteries as per the updated CPCB guidelines45.
  - Systems for wastewater reuse such as Effluent Treatment Plant (ETP) for bus washing and other activities, along with solid waste segregation and Sewage Treatment Plant (STP) should be integrated into depot operations.

## VI. Reference E-Bus Depot Layout

Based on the above recommendations and suggestions, a conceptual safe e-bus depot layout has been developed as illustrated in the following exhibit. The proposed layout requires approximately 5.5 acres of land parcel to accommodate a fleet of 100, 12m long e-buses along with 25[46] charging stations. It includes dedicated isolation zones for damaged e-buses and fire safe area for the storage and repair of battery packs including new, repairable and the repaired units. The depot also provides for essential functional areas such as e-bus parking, isolated

[44] The Ministry of Environment, Forest and Climate Change (MoEFCC) Battery Waste Management Rules, 2022
[45] Battery Waste Management Rules, CPCB
[46] According to the *Renewable-Power Electric Bus Depot Design and Strategies (2025)* document, a commonly followed industry practice is a 4:1 bus to charger ratio, wherein one charger is shared among four buses to balance infrastructure costs and charging requirements.

parking for accidental buses, charging infrastructure, vehicle washing and cleaning bays, workshop and maintenance area, administrative offices, private parking, crew facilities and other utilities. The proposed unidirectional movement in the depot will encourage frictionless flow to avoid any collision / accidents.




| LEGEND | |
|---|---|
| Ⓐ | Compartmentalized E-Bus Zones (20-25 Each) with fire retardant screen |
| Ⓑ | Staff Parking |
| Ⓒ | Security Room |
| Ⓓ | Administration Area including training room, crew area |
| Ⓔ | Battery Storage area with a fire-retardant wall |
| Ⓕ | Workshop & Maintenance |
| Ⓖ | Charging Station - 25 chargers, 1.2m*1m size, pitch 3.5 meter |
| Ⓗ | Generator Set |
| Ⓘ | DISCOM Substation |
| Ⓙ | Tyre Inflation Facility |
| Ⓚ | STP |
| Ⓛ | ETP - Water treatment plant, |
| Ⓜ | Fire Hydrant Water Tank |
| Ⓝ | Washing Area - with water storage tank, etc |
| Ⓞ | Isolation Zone for 2 damaged E-buses |
| Ⓟ | Proposed Emergency Entry/ Exit |
| Ⓠ | Green Shade to maintain microclimate |

*Exhibit 70 Reference to a conceptual E-Bus Depot Plan (*Not to Scale)*

This comprehensive conceptual design layout ensures operational efficiency, safety, and resilience, enabling smooth functioning of the EBES. In particular, a well-planned internal bus-circulation layout, with appropriately located activities and facilities, reduces manoeuvring time and enhances operational efficiency, while simultaneously ensuring compliance with fire, electrical, and overall operational safety standards.

## B. Maintenance Activities

Routine maintenance checks, safety reviews, and systematic logging of incidents are critical to ensure safe, compliant, and uninterrupted e-bus depot operations. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 19 Stakeholder-Specific Maintenance Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Periodic Service Checks | Depot & Central Workshop System |
| 2. | Safety Systems Review | Depot & Central Workshop System; Civil/ Electrical Department |
| 3. | Physical Damage Log | STU/ Public Transport; Depot & Central Workshop System |
| 4. | Safety Incident Log | OEMEB; Depot & Central Workshop System |

*ORMEB: OEM E-Buse Operator

All preventive maintenance activities be meticulously undertaken as per OEM prescribed schedules. Some of the maintenance activities are discussed here-under:

- **Periodic Service Checks:** Undertake periodic i.e. daily / weekly checks of the depot plant and equipment and evaluation of the service bays designated for e-buses, including tools, equipment, and safety measures for servicing and maintenance.
- **Safety Systems Review:** Review of signages, emergency shutdown procedures, and safety equipment for e-bus areas.
- **Physical Damage Log:** Maintain log of physical damage incidents involving e-buses and charging stations.
- **Safety Incident Log:** Maintain log of safety incidents involving e-buses and charging stations.

## *C. Inspection*

Periodic evaluations of training programmes, battery and the charging facilities, and environmental safety measures are essential to ensure safe, compliant, and resilient e-bus depot operations. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 20 Stakeholder-Specific Inspection Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Training Programme Review | Safety Officer, OEM |
| 2. | Battery Area Evaluation | Safety Officer, Civil/ Electrical Department |
| 3. | Environmental Safety Review | Safety Officer, OEM |

The following safety-critical systems and sub systems shall be mandatorily checked during periodic inspections.

- **Training Programme Review:** Periodically (biannually or annually) review training programmes for e-bus handling, operations and maintenance, drivers and the technicians training, and safe manoeuvring practices of e-buses within the depot/ terminal.
- **Battery Area Evaluation:** Evaluate the battery storage and maintenance areas, focusing on ventilation, fire suppression, and emergency access.
- **Environmental Safety Review:** Assess environmental safety measures for e-bus operations, including procedures for hazardous material handling, storage, and safe disposal.

## *D. Monitoring*

Continuous real-time monitoring of weather, energy systems including charging infrastructure, electrical safety, fire risks, and other critical infrastructure is essential to ensure safe, efficient, and resilient e-bus depot operations. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 21 Stakeholder-Specific Monitoring Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Real-Time Weather Integration | Operator's Control Room Team; IMD |
| 2. | Smart Energy Monitoring | Operations/ Technical Team; Operator's Control Room Team |
| 3. | Thermal Imaging Surveillance | Depot & Central Workshop System |
| 4. | Electrical Leakage Monitoring | Depot & Central Workshop System |
| 5. | No-Contact Electrical safety tools | OEMEB; Depot & Central Workshop System |
| 6. | Monitor and integrate SCADA/BMS with dashboards during charging for real-time display of | Operations/ Technical Team; Operator's Control Room Team; OEM |
| 7. | Fire Detection Monitoring | Operator's Control Room Team; OEM |
| 8. | Hydrogen Cooling Systems | Operator's Control Room Team; Depot & Central Workshop System |
| 9. | Smoke Heat Detection | Operations/ Technical Team |
| 10. | Hydrogen Flame Detection | Operations/ Technical Team |

**OEMEB – OEM E-Bus Operator*

The following safety-critical systems and sub-systems shall be mandatorily monitored through various devices as mentioned below:

- **Real-Time Weather Integration:** Public Bus Transport Agency's control room team to integrate IMD's API with the control room ITS for real time tracking of weather. Real-time charging dashboards fed via an IMD API, and site sensors should display ambient temperature, heat index, and short-term forecasts to enable depots to dynamically schedule charging windows.
- **Smart Energy Monitoring:** Integrate and monitor load management software, energy dashboards, and smart metering tools to optimise charging schedules, avoid peak demand penalties, and monitor power quality in real time[47].
- **Thermal Imaging Surveillance:** Install and monitor thermal imaging cameras on or near electrical panels, battery storage areas, charging infrastructure for live monitoring of temperatures and for early identification of overheating to facilitate timely corrective actions.
- **Electrical Leakage Monitoring:** Install and monitor Earth Leakage Relays (ELRs) and Insulation Monitoring Devices (IMDs) on feeder circuits for early detection of electrical leakages and corrective actions, if any.
- **No-Contact Electrical safety tools:** To minimise the risk of electrical injuries particularly from arc flash and arc blast hazards, maintenance personnel should avoid physical contact with energised components and remain outside the arc flash boundary wherever possible, making use of the following amongst others.
  - Use non-contact voltage detectors or electrical testers to confirm the presence or absence of voltage before any work.

[47] Renewable Powered Electric Bus Depot Design and Strategies

- Employ non-contact infrared thermometers for rapid temperature checks of chargers, cables, and panels to identify overheating.
- Use Remote display or wireless multimeters that allow electrical measurements to be viewed from a safe distance.

- **Monitor and integrate SCADA/BMS with e-bus dashboards during charging for real-time display of:**
  - Voltage and current levels
  - Earth faults, insulation degradation
  - Equipment status and error logs
- **Fire Detection and Safety Monitoring:** Integrate the e-bus Battery Management System (BMS) data and charging infrastructure diagnostics into the depot SCADA/ Building Management System to provide early warning of thermal runaway, equipment overheating or electrical faults during charging.
- **Hydrogen Cooling Systems:** Install and monitor cooling systems for $H_2$ cylinders at easily accessible locations.
- **Smoke Heat Detection:** Install and monitor smoke and heat detector systems in all fire prone areas (taking care that false alarms are no raised-on sensing arc welding fumes / smoke).
- **Hydrogen Flame Detection:** Install detection of 'invisible' $H_2$ flame.

## *E. Capacity Building*

Ensuring a rapid, coordinated response to electrical, fire and climate related emergencies in e-bus depot requires robust **emergency planning, regular training, and strictly enforced Standard Operating Procedures (SOPs)**. The **Safety Officer** oversees the entire lifecycle of these safety measures from curation to implementation and execution including frequent drills and rigorous access control to fire-sensitive zones. To ensure **technical accuracy, OEMs** are responsible for collaborating on emergency planning and the development of specialized SOPs. Successful risk management depends on targeted mitigation and compliance by all relevant stakeholders, as detailed in the following enforcement table.

*Table 22 Stakeholder-Specific Monitoring Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Emergency Response Plan and its dissemination | Capacity Building Team; Safety Officer |
| 2. | Train depot/ terminal electrical personnel, drivers and safety officer in | Capacity Building Team; Depot Engineers & Managers |
| 3. | Develop, familiarise the concerned staff and implement SOPs for | Capacity Building Team; OEM |
| 4. | Develop and effectively disseminate amongst related staff - a standard monsoon-readiness protocol | Capacity Building Team; OEM |

| S.N. | Activities | Responsibility |
|---|---|---|
| **5.** | Training of depot/ terminal personnel on natural hazards and safety protocols: | Capacity Building Team; Depot & Central Workshop System |
| **6.** | Flood Simulation Drills | Capacity Building Team; Depot & Central Workshop System; OEM |
| **7.** | Fire Safety Drills | Capacity Building Team; First Responder; Depot & Central Workshop System |
| **8.** | Early Warning Coordination | Safety Officer; Operator's Control Room Team |
| **9.** | Ignition Source Control | Capacity Building Team |
| **10.** | Continuous Supervision | Depot & Central Workshop System |
| **11.** | Supervised Charging Operations | OEM |
| **12.** | Access Control Measures | OEM; Depot & Central Workshop System |
| **13.** | Emergency Contact Access | Depot & Central Workshop System; OEM; First Responders |
| **14.** | Evacuation Planning | Safety Officer |

**Fire responder- (Fire Brigade/ Police/ Ambulance)*

Organise periodic training and retraining of depot/ terminal staff for safe and efficient delivery of services related to EBES:

- **Emergency Response Plan and its dissemination:** Prepare and disseminate amongst concerned personnel, an emergency plan to be followed by operators in case of emergencies.
- **Train depot/ terminal electrical personnel, drivers and safety officer in:**
  - Proper docking procedures
  - Electrical hazard identification and correct PPE usage
  - Lockout-Tagout (LOTO) protocols for safe equipment isolation
  - Arc flash risk mitigation, including use of flame-resistant (FR) clothing and insulating tools
- **Develop, familiarise the concerned staff and implement SOPs for:**
  - Safe energization/de-energization of electrical equipment
  - Routine electrical maintenance, thermographic inspections, and diagnostics
  - Emergency shutdown procedures, including SCADA-assisted isolation
- **Develop and effectively disseminate amongst related staff - a standard monsoon-readiness protocol covering:**
  - Infrastructure inspections

  - Staff training
  - Equipment and duct checks
  - Drainage system checks
  - Leakage tests for sheds in charging infrastructure area
  - Battery storage area
- **Training of depot/ terminal personnel on natural hazards and safety protocols:** Train depot/ terminal personnel including maintenance staff, charging operators, and supervisors periodically say, once a month on:
  - Flood safety procedures
  - Cyclone safety procedures
  - Electrical hazard awareness
  - Emergency isolation protocols
  - Fire safety systems and procedures
- **Flood Simulation Drills:** Conduct mock drills simulating heavy rainfall and depot flooding scenarios to validate preparedness, periodically say once in six months.
- **Fire Safety Drills:** Organize and conduct fire training activities and mock drills with the help of the voluntary fire brigade, periodically say once in six months.
- **Early Warning Coordination:** Establish communication with the IMD, to get prior early warnings on various natural disasters and disseminate the same amongst concerned personnel / display at pre-designated locations.
- **Ignition Source Control:** Enforce strict 'No smoking and No ignition sources' policies within e-bus depot/ terminal premises, display the signs at appropriate locations.
- **Continuous Supervision:** Ensure 24/7 supervision of storage, charging and other hazard sensitive areas.
- **Supervised Charging Operations:** Conduct all charging activities under supervision of trained personnel.
- **Access Control Measures:** Restrict access to hazard sensitive or high-risk zones within the depot.
- **Emergency Contact Access:** Keep emergency contact numbers for response teams readily accessible, also display such numbers at appropriate locations.
- **Evacuation Planning:** Prepare detailed evacuation plans to safely relocate both personnel and assets during emergencies.

## 6.3. Component 3: Charging Infrastructure

The charging infrastructure in context of EBES consists of upstream infrastructure (substation, transformers of power distribution system), switch gear and charging stations. The planning and design of E-Bus charging infrastructure is recommended to adhere to stringent safety, environmental and operational standards to ensure reliable, safe and secure charging of e-buses. These standards address key aspects such as site selection, environmental suitability, ventilation, protection from rain and direct sunlight and equipment installation and commissioning. Special attention is paid to fire safety, protection against flooding, and selection of charging infrastructure areas free from corrosive environment. Additionally, robust surveillance and monitoring systems are essential for operational oversight, including video surveillance, access control, and fire alarm integration. Together, these guidelines aim to create resilient, safe, and efficient charging environments that support the long-term sustainability of EV ecosystems. Refer Annexure C for detailed available standards for charging system.

## A. Planning & Design Recommendations

The planning and design of e-bus charging infrastructure must be based on fleet characteristics, charging demand, site conditions, and long-term operational requirements, while ensuring electrical, thermal, water, cyber, and structural safety. These recommendations outline an integrated approach aligned with national and international standards to ensure safe, resilient, interoperable, and future-ready charging systems that support reliable depot operations, grid stability, and emergency preparedness.

Detailed planning, design, installation and other standards recommendations, aimed at enhancing charging infrastructure safety and protection are presented in the respective sections here under.

### I. Electrical Safety

***Planning Recommendations***

*Table 23 Stakeholder-Specific Electrical Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **ELECTRICAL SAFETY** | | |
| **1.** | Site Condition Assessment | Civil/ Electrical Department, Planning Team |
| **2.** | Planning for Accessible Distribution Systems | Civil/ Electrical Department, DISCOM |
| **3.** | Provide Transformer with Earthing Connections | Civil/ Electrical Department, DISCOM |
| **4.** | Provision for Medium Voltage – Low Voltage Integration | Civil/ Electrical Department, Planning Team |
| 5. | Acquiring Compact Switchgear Design | Civil/ Electrical Department |
| 6. | Maintaining physical segregation between electrical components | Civil/ Electrical Department |
| 7. | High Voltage Area Identification | Civil/ Electrical Department |
| 8. | Maintaining Pre-Charging Time Gap in e-bus | Charging System Provider |
| 9. | Providing Time Gap between successive charging Sessions | Charging System Provider |
| 10. | Charging Status Confirmation | Charging System Provider |

Following finalisation of e-bus specification[48], fleet size in the depot/ terminal and charging requirement, the **public bus transport agencies or depot operator in consultation with Charger OEMs and or Bus OEMs**, shall determine the required number, type, rating of charging equipment and associated infrastructure. Based on the charger ratings and total number of

[48] E-Bus Specification includes battery capacity, on-board charging system type, charging interface and its location on the vehicle.

chargers, the **connected electrical load shall be assessed and submitted to the DISCOM**, which shall be responsible for planning, approving, and provisioning the requisite upstream electrical infrastructure, including transformers, substations and related items. Other aspects for consideration for safe and efficient operation of the charging system are brought out herein:

- **Site Condition Assessment:** Following evaluation of depot/ terminal site characteristics such as low-lying area prone to floods, seismic zone, extreme temperature and dusty environmental conditions, appropriate design measures should be incorporated. These include providing a **higher charger pedestal height (minimum 450 – 600mm)** , ensuring flood resilient **cable ducting and connectors of charging stations** and designing sheds of **appropriate height and width to enable proper ventilation.** Adequate provisions must also be made to safeguard **bus charging connection points** during operation from adverse weather conditions. Additionally**, all socket outlets and power supply interfaces** should be planned and installed above the **site's high flood level** to ensure safety and operational reliability.
- **Planning for Accessible Distribution Systems:** While planning for charging systems, ensure that all distribution systems are easily accessible to undergo regular inspection and maintenance.
- **Provide Transformer with Earthing Connections:** Connect the transformer cabinet, bracket, foundation section steel and the casing separately and reliably with protective conductor with the help of complete fasteners and anti- loosening parts to provide for effective earthing for the transformer.
- **Provision for Medium Voltage – Low Voltage Integration:** Plan to connect the medium and low voltage distribution systems using sectional unit bus configurations for their proper integration.
- **Acquiring Compact Switchgear Design:** Provide a Switchgear that is compact, oil-free and designed for minimal maintenance or maintenance-free operation.
- **Maintain physical segregation between electrical components:**
    - Low Voltage (LV) and High Voltage (HV) panels
    - Charging bays and control electronics
    - Operator access zones and live terminals
- **High Voltage Area Identification:** Use color-coded conduits, warning signage, and barriers to demarcate HV areas for clear identification.
- **Maintaining Pre-Charging Time Gap in e-bus:** Ensure that the necessary time interval (e.g.5-10 mins), between completion of e-bus operation and commencement of bus charging, is provided before the bus is taken up for charging and that the bus is in "park mode" before charging, with the parking brake engaged and the ignition off.
- **Providing Time Gap between successive charging Sessions:** Maintain a 5–10-minutes cooling period between successive charging sessions by the chargers.
- **Charging Status Confirmation:** A ***"Charger Connected"*** message shall appear on the instrument cluster, confirming a secure connection and charging initiation.

### *Design Standards*

Following communication of the connected load requirement, site details and charger specification (type, rating, quantity and related parameters) to the DISCOM, the **planning, design and provisioning of the sub-station, transformers, switch gears and associated upstream electrical infrastructure shall be the responsibility of the DISCOM**. The **downstream electrical connections** from the DISCOM transformer up to the charging equipment within the depot/terminal shall be undertaken by the **public bus transport agencies (PBTA)** in close coordination with the DISCOM. On the depot/terminal side, the charging system shall comply with the following applicable standards among others.

- All electrical equipment installed in EV charging station shall **comply with Central Electricity Authority regulations,** specifically the Technical Standards for Connectivity of Distributed Generation Resources (2013) and Safety and Electric Supply Measures (2023), as amended from time to time.
- **Local building codes and safety standards** for materials used and the installation of charging stations procedures.
- **EV Conductive Charging System**- General aspects: International standards: IEC 61851-21:2001, and IEC 61851-1:2001[49].
- BIS Standards - **IS 17017 and IS 15118** together form the foundation of **electric vehicle (EV) charging ecosystem,** ensuring a safe, interoperable, and future-ready infrastructure. By harmonising hardware (IS 17017) and communication (IS 15118), a robust, user-friendly, and sustainable EV charging ecosystem, which supports mass EV adoption and integrates with the evolving energy grid, is created.
- Inductive charging system Standards:
  - Standards and specifications for equipment required for the **wireless transfer of electrical energy** from the power grid to electric road vehicles: **IEC 61980**
  - **Safety and interoperability requirements** for on-board equipment enabling wireless transfer of magnetic field energy for charging electric vehicles: **ISO 19363**

**RECOMMENDED STANDARDS**

- ***All chargers shall comply:*** *IS 17017, IEC 61851, IEC 60364, IEC 62196, and IEEE 519 standards.*
- ***EV Conductive Charging System (AC / DC):*** *Indian Standards: AIS138- part 1 & Part 2; International Standards.: IEC 61851 – 1:2001/21:2001 /22 / 23 & Ministry of Power Guidelines - system design and equipment installation aspects of conductive charging infrastructure*
- ***Charging Process Regulation:*** *IEC 61851-23, IEC 61851-24 along with their derivate EN standards*
- ***EV Charging Ecosystem:*** *BIS Standards- IS17017 (Harmonising Hardware) and IS15118 (Communication)*
- ***High Level Communication via Power Line Communication:*** *Vehicles and the chargers: EN ISO 15118-3 for cabling, Control Pilot contact pin IEC 61851-23 (for vehicles) and IEC 61851-24 (for chargers)*
- ***Earthing Connection for Charging Infrastructure:*** *IEC 60364-54*

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[49] https://www.mdpi.com/2571-6255/8/4/159

  - Recommended practices on electric vehicle **inductively coupled charging**: **SAE J1773**

- **Safety related warning labelling practice** on components, sub-systems, and systems – Contents, placements, and durability through-out product life cycle i.e., initial use to disposal at End of Life (EOL): **SAE J2936 2025.**
- Standard for connecting the **high and low voltage transformers** with **non-combustible materials**, meeting safety requirement and having enclosures with a minimum ingress protection rating. General standards: **IS 2026 & IEC 60076.**
- In transformer and distribution system, **use Copper core, XLPE insulation, and flame-retardant cable** with optimized routing and proper installation for safety and reliability.
- Apply **protective measures** where cables are exposed to mechanical stress, vibration, moisture, or corrosive substances.
- **Provide for distribution boxes** to comply with electrical safety standards to prevent electric shock.
- For special power transformers, use **metal or insulated-sheathed cables, buried, and routed through steel conduits to ensure lightning protection.**
- Install **surge protection devices** and lightning arrestors and maintain to prevent damage during electrical storms.
- Maintain earth resistance **<1 ohm for all exposed and conductive equipment**. Ensure equipotential bonding across charger cabinets, dispensers, distribution panels, and nearby metallic structures.
- All electric vehicle charging stations shall be provided with an **earth continuity monitoring system** that disconnects the supply if the earthing connection to the vehicle becomes ineffective.
- Power supply cables used at charging stations or charging points shall confirm to IEC 628931[50], compliant with the construction, performance test and material type for durable and flexible cable sheathing.
- Integrate electrical infrastructure with city disaster response systems for proactive shutdown.
- Equip **chargers to detect faults** and system failures-
  - Ground fault detection
  - Overcurrent protection
  - Overheating protection
  - Emergency shutoff switches
- Install **mandatory protection devices on all circuits** and charging station:
  - Residual Current Devices (RCDs) rated ≤30 mA

50 IEC 62893

  - Overcurrent Protection Devices (OCPDs)
  - Surge Protection Devices (SPDs) compliant with IEC 609473.
- Design for serviceable life of the charging infrastructure to be at par with life of the e-buses.
- Provide **power quality meter (PQM),** with readings monitored by both e-bus operator and electric utility engineer, for EVSE installation above 50kW.
- Suspend charging operations **and turn off the power to all EVSEs** in the event of **lightning and thunder.**
- Develop **standard operating procedures (SOPs) for maintenance and safe operations** of charging infrastructure, guiding the staff on daily activities and safety protocols.

## II. Thermal Safety

### *Planning Recommendations*

*Table 24 Stakeholder-Specific Thermal Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **THERMAL SAFETY** | | |
| **1.** | Charger Thermal Protection | Civil/ Electrical Department; Charging system Provider |
| **2.** | Adequate Ventilation Provision | Civil/ Electrical Department; Charging system Provider |
| **3.** | Ambient Temperature Compliance | Civil/ Electrical Department; Charging system Provider |
| **4.** | Thermal Sensor Installation | Charging system Provider |
| **5.** | Fire Detection Systems | Charging system Provider |
| **6.** | Optimise Charging Schedule | Charging system Provider/ In charge; Depot Management |
| **7.** | Provision for Temperature-Tolerant Chargers | Charging system Provider |
| **8.** | Provision for EV Charging Station Fire Protection | Charging system Provider; Depot Management |

- **Charger Thermal Protection:** Provide shaded canopies or truss structures to reduce heat buildup during charging and ensuring thermal protection. Where feasible, incorporate site level vegetation or green roofs to lower microclimate temperatures. For chargers housed within enclosed or semi-enclosed spaces, use heat-resistant enclosures and incorporate appropriate active or passive ventilation systems to effectively manage thermal loads.
- **Adequate Ventilation Provision:** Provide adequate ventilation around the charging stations and ensure temperature control, especially in indoor charging installations, to maintain proper airflow, prevent heat buildup, and support the optimal ambient conditions required for safe and efficient battery charging.
- **Ambient Temperature Compliance:** Maintain ambient temperature of charging station as specified by OEM charging system provider to meet the requirement of normal charging for electric vehicle battery.

- **Thermal Sensor Installation:** Install thermal sensors inside charger cabinets for early detection and warning of thermal episodes.
- **Fire Detection Systems:** Install early detection and warning systems pertaining to occurrence of smoke, gas, heat, and flame for initiating necessary fire safety measures.
- **Optimise Charging Schedule:** Schedule charging at night/ early morning to minimise thermal stress on charging equipment.
- **Provision for Temperature-Tolerant Chargers:** Acquire and use temperature-tolerant charger models.
- **Provision for EV Charging Station Fire Protection:** Conventional fire suppression methods may be ineffective or unsafe for EV or an EV charging station fire. Therefore, appropriate advanced fire suppression systems shall be provided, including **Clean Agents, Aerosol systems, and AVD (Aqueous Vermiculite Dispersion) fire extinguishers** to effectively manage such fire risks.

***Design Standards***

- Equip the **charging area with fire-fighting equipment** such as automatic fire detection and suppression system along with manual fire extinguishing system and ensure that entire staff is trained in its use besides in safety communication protocols.
- **Power supply cables** used at charging stations or charging points shall confirm to IS 17505 (Part 1)[51] or applicable standards for fire survival cables. Ensuring compliance with established requirements for fire resistance and operational safety.
- As an initiative for early detection and prevention of fire, **install infrared and thermal imaging technologies** in detecting temperature anomalies. When integrated with building automation systems, these provisions enable real-time monitoring and early detection of potential fire risks for necessary preventive action.
- Provide **remote/automatic shut-off and sectional isolation options** in the operator's control room and near switchgear for automatic shut-off in case of smoke/ heat buildup.

## III. Water Protection

***Planning Recommendations***

*Table 25 Stakeholder-Specific Water Protection Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **WATER PROTECTION** | | |
| **1.** | Installation of Switchgear/ SCADA on a flood safe elevated Control Rooms / Pedestal | Civil/ Electrical Department; Charging system Provider |
| **2.** | Provision of Remote Isolation Systems | Operator's Control Room Team; Charging system Provider |
| **3.** | Implementation of Site Grading Measures | Civil/ Electrical Department |
| **4.** | Provision of Cable Trench Depth | Civil/ Electrical Department; Charging system Provider |

[51] IS 17505 (Part 1)

| S.N. | Activities | Responsibility |
|---|---|---|
| 5. | Laying out High-Voltage Cable Routing | Civil/ Electrical Department; Charging system Provider |
| 6. | Flood-Safe Charger Siting | Civil/ Electrical Department; Charging system Provider |
| 7. | Elevated Electrical Equipment positioning | Civil/ Electrical Department |
| 8. | Provision for Weather Shielding Measures | Civil/ Electrical Department |
| 9. | Installation of Humidity Control Systems | Charging system Provider |

- **Installation of Switchgear/ SCADA on a flood safe elevated Control Rooms / Pedestal:** Install the switchgear and SCADA/EMS systems in a flood-safe elevated control rooms or on elevated platforms with a minimum of 450 – 600mm[52] above ground level or above local flood benchmarks whichever is higher.
- **Provision of Remote Isolation Systems:** Provide remote shut off and sectional isolation options in the control room and near switchgear in case of water ingress.
- **Implementation of Site Grading Measures:** Provide / implement site grading and trenching to channel surface runoff away from charging bays and electrical equipment.
- **Provision of Cable Trench Depth:** All cables of the charging system are recommended to be installed in trenches with a depth of approximately 450 mm to accommodate 415V systems.
- **Laying out High-Voltage Cable Routing:** Route high voltage cables away from potential water ingress paths, avoiding undercarriage-exposed zones and low-lying conduits.
- **Flood-Safe Charger Siting**: Avoid installation of charging stations in low-lying outdoor areas or locations prone to water accumulation or flooding. Mount Charging equipment at a safe height (400 - 600 mm above historic flood levels)[53] to prevent damage from rain/water seepage or flooding.
- **Elevated Electrical Equipment Positioning:** Position the crucial electrical equipment like transformers, RMUs, and LT panels at elevated levels (450 - 600mm above historic flood levels) to prevent damage from water ingress.
- **Provision for Weather Shielding Measures:** To improve Charging Systems longevity, shield the chargers from weathering effects by limiting exposure to rain, storms, heatwaves etc which can cause degradation.
- **Installation of Humidity Control Systems:** Install appropriate equipment and system in regions with frequent wet weather to monitor and control air humidity levels.

***Design Standards***

- House chargers and distribution boxes in a **minimum IP65 rated enclosures[54]** depending upon local context as per **AIS-138**, to ensure protection against dust and water ingress.

[52] Source: Internal Discussions with experts and Workshop Insights
[53] Source: Internal Discussions with experts and Workshop Insights
[54] Guide for EV Charger IP (Ingress Protection) Rating

- Equip the chargers with automatic disconnection mechanisms in case of ground fault, insulation failure, or water detection, as per AIS-138 Part 2, Clause 7.0.
- Seal battery packs, connectors, wiring harnesses, and motor enclosures using **industry-standard waterproof gaskets and hydrophobic coatings.**
- Position socket outlets and connector storage **between 400 mm and 1500 mm** above ground level, in accordance with AIS-138 Part 1.

**RECOMMENDED STANDARDS**

- ***Chargers with automatic disconnection mechanism:*** *AIS-138 Part 2, Clause 7.0.*
- ***Socket outlets and connector storage:*** *AIS-138 Part 1*

- Install **flood alarms and moisture detection sensors** at substations.
- Enable chargers with remote diagnostics and control to manage risk during event of flood, water logging, extreme temperatures etc.
- Install **thermal, humidity, and water ingress** sensors inside **charger cabinets** for early warning.

## IV. Cyber Security

### *Planning Recommendations*

*Table 26 Stakeholder-Specific Cyber Security Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **CYBER SECURITY** | | |
| **1.** | Implementation of Cybersecurity Protection Measures | Charging System Provider |
| **2.** | Secure Human Machine Interfaces (HMI) | Charging System Provider |
| **3.** | Provision for Physical Port Security | Charging System Provider |
| **4.** | Network Segmentation Strategy | Charging System Provider |
| **5.** | IP Address Validation | Charging System Provider |

- **Implementation of Cybersecurity Protection Measures:** Implement appropriate cybersecurity measures such as installation of firewalls, application of authentication measures, encryption of data, and installation of anti-virus programs to protect the product, the network, its system and the interface from security breaches, unauthorized access, leakage and data theft.
- **Secure Human Machine Interfaces (HMIs):** Secure HMIs (touchscreens, card readers) with multi-factor authentication.
- **Provision for Physical Port Security:** Provide for port by way of locking USB and Ethernet ports; using tamper-proof enclosures.

- **Network Segmentation Strategy:** Implement network segmentation strategy by isolating Electric Vehicle Charging Station (EVCS) networks from public internet and internal depot systems. In other words, provide a standalone internet connectivity for the charging system.
- **IP Address Validation:** Validate the IP addresses & allow only pre-approved clients to access the system.

***Design Standards***

- Use **Open Charge Point Protocol (OCPP) 2.0.1** or higher with Transport Layer Security (TLS) encryption and mutual authentication.
- **SQL Injection** - Use parametrized queries to distinguish code from data.

## V. Structural Safety

***Planning Recommendations***

*Table 27 Stakeholder-Specific Structural Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **STRUCTURAL SAFETY** | | |
| **1.** | Provide Safe Charger Siting/ Pedestal | Civil/ Electrical Department; Charging system Provider |
| **2.** | Implement Corrosion Protection Measures | Depot Management; Charging system Provider |
| **3.** | Maintain Minimum Safety Clearance between charger/ "Charge to E-Bus" during charging | Depot Management; Charging system Provider |
| **4.** | Secure Charger Enclosures | Depot Management; Civil/ Electrical Department |
| **5.** | Install Surveillance Monitoring Systems | Depot Management; Charging system Provider |
| **6.** | Implement Traffic Zone Demarcation | Depot Management; Charging system Provider |
| **7.** | Provide Vehicle Alignment Aids | Depot Management; Charging system Provider |
| **8.** | Install Physical Impact Barriers | Depot Management; Charging system Provider |

- **Provide Safe Charger Siting/ Pedestal:** Locate charging stations away from potential fire or explosion, hazards and place them at higher pedestals in areas free form dust, corrosive gases, or the downwind side of prevailing winds.
- **Implement Corrosion Protection Measures:** To prevent corrosion, use EVSE equipment with a waterproof rating of **IP65/IP66 or higher,** and install **water detection sensors** to enable automatic power shut-off besides other corrosion prevention measures such as painting of all corrosion prone metallic surfaces.
- **Maintain Minimum Safety Clearance between chargers/ " Charger to e-bus" during charging:** Maintain proper distance, a **minimum 1.5-2 meters** between the charging units, charging units and the e-buses under charging and parked buses.

- **Secure Charger Enclosures:** House the charging stations in a fenced, secure and tamper resistant housing to prevent damage during protests and vandalism.
- **Install Surveillance Monitoring Systems:** Install motion detectors and CCTV and cameras near the charging infrastructure.
- **Implement Traffic Zone Demarcation:** Implement Traffic zone demarcation system by defining and clearly marking traffic zones around the chargers to prevent operational accidents and human negligence, and to avoid inter-vehicular friction/ vehicular collisions with chargers.
- **Provide Vehicle Alignment Aids:** Install vehicle alignment aids in the charging zones by providing floor-level stoppers/ guides to help drivers position buses optimally to prevent collision between e-buses and charging infrastructure.
- **Install Physical Impact Barriers:** Install physical barriers or bollards near charging stations to safeguard equipment from accidental or deliberate vehicular impacts.

## VI. General Safety Measures

*Table 28 Stakeholder-Specific Common Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **GENERAL SAFETY MEASURES** | | |
| **1.** | Connected Load Provision for Grid Resilience | Civil/ Electrical Department; Charging system; DISCOM |
| **2.** | Resilient Upstream Infrastructure – Redundant Grid Provision | Civil/ Electrical Department; Charging system; DISCOM |
| **3.** | Charger to Bus Ratio and Smart Power Management | Charging system Provider |
| **4.** | Safety from Technological Obsolescence | Charging system Provider |
| **5.** | Emergency Action Plan | Civil/ Electrical Department; Charging system Provider |
| **6.** | Surveillance Requirement | Charging system Provider |

### *Connected Load Provision for Grid Resilience*

- **Adequate Connected Load:** Obtain electricity connection (connected load) in the bus depot/ terminal, from the electric utility, of adequate capacity for the projected e-bus deployment during next 10 - 30 years.
- **Dual Power Feeds:** Wherever feasible and allowed as per norms of DISCOMs, maintain dual/distributed power feeds to manage incidents of power failures.
- **On-site Solar Integration:** Install rooftop or elevated solar panels on administration building, parking structure or on top of charging infrastructure shed. Designs should be guided by shadow analysis, structural load capacity, and estimated solar potential (e.g., kWh/m²/year)[55].
- **Renewable Backup Systems:** Integrate charging system with renewable sources (solar + hybrid inverters) for backup during emergency situations.

[55] Renewable Powered Electric Bus Depot Design and Strategies

- **Battery Energy Storage:** Pair the charging infrastructure with a Battery Energy Storage System (BESS) to provide emergency power backup and manage peak load demands during blackouts or grid failures. Integration with the Energy Management System (EMS) is critical.
- **Smart Grid Readiness:** Depots should be designed to support future integration with smart power grids. While Vehicle-to-Grid (V2G) is still in the pilot stage in India, provision of bi-directional chargers and compatible electrical systems be considered in forward-looking depots, subject to state DISCOM regulations[56].
- **Flood-Resilient Equipment:** Position distribution transformers at elevated level, Ring Main Units (RMUs), and LT panels above historical flood levels.
- **Upstream Breaker Control:** Ensure that the upstream Moulded Case Circuit Breaker (MCCB) or Earth-Leakage Circuit Breaker (ELCB) for the AC power supply is OFF, when EVSEs are not in operations.
- **Utility Compliance Rules:** Ensure compliance to local regulations of distribution network operators who normally specify management protocols, testing frequency, and whether 24-hour access is required by the distribution network operators.
- **Transformer Redundancy:** If a depot/ terminal requires a transformer of more than 1MW, PTA are advised to consider provision of multiple transformers of up to 2MW to deliberately create a redundancy, to enhance reliability and to ensure continued operations in case one unit fails.
- **Islanding / Micro-grid Operation Capability:** The EV charging station, integrated with available distributed energy resources (such as solar PV, battery energy storage systems, or backup power sources), shall be capable of operating in islanded or micro-grid mode during grid outages or disaster conditions. Adequate protection systems, including electrical isolators and anti-islanding mechanisms, shall be provided to ensure safe disconnection from the grid and to prevent any reverse power flow during such operation.

***Resilient Upstream Infrastructure – Redundant Grid Provision***

- **Load Estimation:** Load estimation to consider e-bus type, fleet size, and charger configuration. A 100-bus depot typically requires 4.5–6.0 MVA[57], with an additional 25–30% load margin planned for future expansion and resilience.
- **DISCOM Connection & Process:**
    - Obtain HT/EHT connection (typically 11 kV or 33 kV) based on load.
    - Submit and align with DISCOM's Supply Code Regulations.
- **Survey & Assess Land Requirements:** Survey the site and assess land parcel requirement considering the following amongst others:
    - Adequate space for Electrical Substation (ESS) varies with load and voltage level.
    - Space for transformers, switchgear, metering, and safety clearance zones as per DISCOM regulations
- **Demand Estimate & Infrastructure Execution:** Discom prepares:

[56] Renewable Powered Electric Bus Depot Design and Strategies
57 CESL - Standard Operating Procedure (SOP) for developing up upstream depot infrastructure for e-bus operations, 2022

  - Demand note and outlines upstream network augmentation needs.
  - Ensures test reports, safety certificates, and equipment clearances are available.
  - Evaluate options to execute works via DISCOM or in house (STU), with supervision charges.
  - Execution by DISCOM may be preferred for system expertise and integrated responsibility.
- **Elevation & Flood Protection:** Evaluate the site location and equipment placement for flood protection.
  - Positioning of ESS and transformers on raised plinths (minimum 0.6–1.0 m above 100-year flood level).
  - Provision of stormwater drainage, sump pumps, and waterproof cable trenches.
  - Ensuring graded slope and permeable pavement for effective runoff.
- **Safety and Protection Systems:** Ensure availability of protection and safety systems for the following amongst others:
  - Lightning protection, earthing, and surge arrestors for all equipment.
  - Use of IP67+ rated enclosures for outdoor electrical gear.
  - Integration of real-time monitoring (SCADA/BMS) for overloads, short-circuits, and moisture ingress.

***Charger to Bus Ratio and Smart Power Management***

- **Bus - Charger Ratio:** A commonly followed practice is a 4:1 bus-to-charger ratio, where one charger is shared by four buses to balance infrastructure costs and charging demand58. Additionally acquire 2-3 more chargers as repair and maintenance spares.
- **Smart Power Management:** When multiple buses are charged simultaneously, smart power management be provided to prevent overloading the grid. For example, depots may use overnight slow charging for full battery replenishment, complemented by daytime opportunity charging using short duration, high-power top-ups.

***Safety from Technological Obsolescence***

- **CCS2 Protocol Adoption:** Adopt and enforce the CCS2 protocol across all charging infrastructure to ensure universal compatibility and interoperability, allowing e-buses to charge seamlessly and maintaining system resilience if any component fails.
- **OCPP-Compliant Chargers:** Enforce the use of Open Charge Point Protocol (OCPP) compliant chargers and Charging Management System (CMS) for better interoperability[59].
- **Service Upgrade Agreements:** Ensure regular upgrade and service agreement with the charging system provider.
- **Software Firmware Updates:** Regular software and firmware upgrades need to be contracted.

[58] Renewable Powered Electric Bus Depot Design and Strategies (2025) – Changing Transport
[59] Roadmap on EV Charging Infrastructure technologies to overcome hindrances to E-Mobility (Vol 3) – Dept of Science & Technology

- **OCPI Interoperability Support:** Ensure provision of Open Charge Point Interface (OCPI) to facilitates network-to-network interoperability.
- **Smart Grid Integration:** Implement smart grid integration with energy storage for dynamic power management.

***Emergency Action Plan***

- **Emergency Response Plan:** Prepare an emergency response plan that instructs operators about what to do in case of an emergency.
- **Pre-Operation Approval:** Obtain pre-operation approval of a trained and certified technician or third-party engineer, duly authorised by appropriate Certification Agency before operating the EVSE.

***Surveillance Requirement***

- **Safety Monitoring Systems:** Install safety monitoring systems including video surveillance, intrusion alarm and access control at entry and exit points of depot/ terminal charging stations
- **Expanded Camera Coverage:** Increase coverage by cameras to the charging area and business counters and integrate them with the fire alarm system. Position the cameras and other equipment securely to avoid damage.
- **Continuous Data Recording:** Support all surveillance system with 24-hour recording capacity, with minimum data retention period of 30 days and capability for low-light or nighttime imaging.

## B. Maintenance Activities

A preventive and corrective maintenance regime aligned with OEM-prescribed schedules shall be implemented to prevent occurrence of any faults and to identify defects early, maintain equipment integrity, and minimize operational and safety risks. Regular pre-operational checks, routine inspections, and prompt fault reporting form the backbone of effective maintenance management for charging stations. Successful implementation requires clearly defined mitigation actions by relevant stakeholders, as detailed in the following table to support enforcement and compliance.

*Table 29 Stakeholder-Specific Maintenance Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Preventive Maintenance Schedules | Charging System Provider; OEMEB |
| 2. | Routine Equipment Inspections | Charging System Provider; Depot & Central Workshop System |
| 3. | Waterproofing Integrity Verification | Charging System Provider; OEMEB |
| 4. | Pre-Operational Safety Checks | Charging System Provider; Depot & Central Workshop System |
| 5. | Fault Tagging Procedure | Charging System Provider |

**OEMEB – OEM E-Bus Operator*

All preventive maintenance activities be meticulously conducted as per OEM-Charging System prescribed schedules. Some of the maintenance activities are discussed here-under:

- **Preventive Maintenance Schedule:** Carryout preventive maintenance activities periodically as per schedules and tasks prescribed by the OEM-Charging Systems.

- **Routine Equipment Inspections:** Carry out daily, weekly and monthly inspection of charging station equipment with respect to tasks prescribed by the OEM-Charging Systems.
- **Waterproofing Integrity Verification:** Verify waterproofing integrity of Charging sub-systems/ equipment, amongst other tasks, during scheduled preventive maintenance routines.
- **Pre-Operational Safety Checks:** Conduct daily pre-operational checks to ensure serviceability before commencement of charging operations to avoid failures and potential safety hazards. After the day's operations, report any damage or malfunctioning for corrective action.
- **Fault Tagging Procedure:** In the event of any abnormality, attach a fault tag to it immediately and report the matter to Depot Workshop System/ Charging In-charge for corrective action.

### C. Inspection

Charging infrastructure inspections are critical to ensuring electrical safety, regulatory compliance, and operational reliability of e-bus depots. These activities encompass statutory certifications, periodic third-party audits, and seasonal preparedness checks of electrical, structural, and drainage systems to proactively identify risks, verify system integrity, and maintain safe charging operations under normal and extreme conditions. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 30 Stakeholder-Specific Inspection Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | EVSE Commissioning Certification | DISCOM, Civil/ Electrical Department |
| 2. | Statutory Electrical Approval | DISCOM, Civil/ Electrical Department |
| 3. | Periodic Safety Inspections | Charging System Provider, Safety Officer |
| 4. | Drainage System Inspection | Safety Officer, Civil/ Electrical Department |
| 5. | Lightning Protection Validation | Charging System Provider, Safety Officer |
| 6. | Pre-Monsoon Structural Checks | Charging System Provider, Safety Officer |
| 7. | Emergency Inspection SOPs | Charging System Provider, Safety Officer |

The following safety-critical systems and components shall be mandatorily checked during periodic inspections.

- **EVSE Commissioning Certification:** DISCOM engineer to inspect and certify the EVSEs, before commissioning. Validity of said certificate be verified during periodical inspections.
- **Statutory Electrical Approval:** Get inspection and approval by the State Electrical Inspectorate for EVSE installation above 200kW[60]. Validity of said certificate be verified during periodical inspections.
- **Periodic Safety Inspections:** Organise periodical (say **quarterly) inspections** at charging station preferably by a third party and maintain the records for future reference. In that:

[60] Electrical Safety Hazard Mitigation at Bus Depots for Electric Vehicle Supply Equipment (EVSE) – ISGF 2022

  - Examine the charging station equipment, operation, maintenance standards, and SOPs to ensure safe charging practices.
  - Inspect the entire electrical infrastructure supporting e-bus operations for compliance with electrical safety standards.

- **Drainage System Inspection:** Carry out periodic inspection of sump pits, grates, and drainage systems to ensure unobstructed water and effluents flow.
- **Lightning Protection Validation:** Ensure functionality of lightning protection systems prior to monsoon and cyclone seasons through visual inspection and electrical testing. This includes checking air terminals, down conductors, and earthing systems for integrity, as well as verifying grounding resistance (≤10 ohms) and electrical continuity[61]. Surge protection devices shall also be inspected for proper operation. All identified issues must be rectified before the season.
- **Pre-Monsoon Structural Checks:** Conduct pre-monsoon body inspections and structural reinforcements for chargers, their mountings and other electrical equipment.
- **Emergency Inspection SOPs:** Develop SOPs for inspections, shutdown, deployment of sandbags during emergencies.

## *D. Monitoring*

Regular monitoring the operating parameters of the chargers and related sub-systems / components, to facilitate early detection of any defect / malfunction for necessary corrective action. Such monitoring shall help in preventing failures. Effective implementation requires targeted mitigation actions by relevant stakeholder, as outlined in the following table for enforcement and compliance.

*Table 31Stakeholder-Specific Monitoring Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Periodic check for Smart Charger Protection | Charging System Provider, OEM |
| 2. | Operability of Emergency Shutoff Switch | Charging System Provider, OEM |
| 3. | Monitor the Central SCADA system | Charging System Provider, Operator's Control Room Team |
| 4. | Use of Onboard self-diagnostics | Charging System Provider |
| 5. | Keep Track of Insulation Failure Alerts | Charging System Provider, Safety Officer |

The following safety-critical systems and components shall be mandatorily monitored through various devices as mentioned below:

- **Periodic check for Smart Charger Protection:** Periodically undertake functionality checks of smart charger for auto cut-off & overheat protection
- **Operability of Emergency Shutoff Switch:** At scheduled intervals, check operability and easy accessibility to emergency shutoff switch installed on each charger.
- **Monitor the Central SCADA System:** Monitor following parameters using the pre-integrated chargers into central SCADA system:

[61] The complete guide to lightning protection system inspection – LPS France

- Real-time monitoring of voltage, current, earth leakage, temperature, and system health
- Remote shutdown, fault isolation, and auto-disconnect

- **Use of onboard self-diagnostics** system, installed on each unit, for regular:
  - Detection of current leakage
  - Recognition of Arc fault
- **Keep Track of Insulation Failure Alerts:** Keep track of failure alerts in the event of insulation resistance.

## *E. Capacity building for staff engaged for charging systems – Operations and Maintenance*

Training and operational preparedness are critical to ensuring safe and reliable charging infrastructure operations. This section outlines mandatory training modules, standard operating procedures, and emergency response practices for depot personnel to prevent electrical hazards, manage fire risks, and ensure personnel safety during e-bus charging and related activities. Effective implementation requires targeted mitigation actions by relevant stakeholder, by imparting training for the activities/ functional areas as outlined in the following table for enforcement and compliance.

*Table 32 Stakeholder-Specific Capacity Building Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Basic features of the charging system | Charging System Provider; Capacity Building Team |
| 2. | Docking and emergency handling | Charging System Provider; Capacity Building Team |
| 3. | SoPs to prevent electrical mishaps | Charging System Provider; Safety Officer |
| 4. | Fire-fighting Equipment | Charging System Provider; Capacity Building Team |
| 5. | Fire-fighting operations activities and mock drills | Capacity Building Team; First Responders; Charging system |
| 6. | Site-specific SOPs | Safety Officer |
| 7. | Ensure Safety for personnel while charging | Charging system; Capacity Building Team |

Train technicians and other related staff, deployed in the electrical and charging infrastructure, for the following amongst others:

- **Basic features of the charging system:**
  - Overall construction and operations of the charging system – the chargers, their construction and functioning, operating procedures, controls, electricity input side details from transformer to chargers, output side details from chargers to e-buses, etc.
  - Safe start-up, shutdown, and isolation procedures
  - Arc fault identification and mitigation
  - Safety and emergency provisions

  - LOTO (Lockout-Tagout) safety practices
- **Docking and emergency handling:** Training concerned staff in optimal docking of e-buses for charging and in emergency handling plans:
  - Proper procedure of e-bus docking for charging, identification and connecting appropriately matching connector, safety protocols during the process.
  - Emergency handling plans/ SOPs that instruct operators to handle emergencies.
- **SOPs for the following to prevent electrical mishaps** turning into electrical fire – understanding of:
  - optimal charging practices, and
  - operations and maintenance of the transformers.
- **Fire-fighting Equipment :**
  - familiarisation with the location of fire-fighting equipment
  - handling and use of fire-fighting equipment
  - familiarisation with safety communication protocols
- **Fire-fighting operations, activities and mock drills** by fire brigade / Agency:
  - Regularly organize and conduct training on fire-fighting activities
  - Periodically arrange mock drills for fire fighting
- **Site-specific SOPs to cover:** Prepare and disseminate site-specific SOPs for the following amongst others:
  - cable management and safe plug-in/unplug practices
  - routine maintenance and diagnostic testing
  - fault escalation, communication, and containment procedures
- **Ensure Safety for personnel while charging**: Train in ensuring safety of personnel while charging as follows:
  - Only qualified and certified technicians to perform charging operations
  - All personnel to wear rubber gloves, face shield, personal protective equipment (PPE), flame resistant clothing, adhere to strict procedures and maintaining a secure charging environment.
  - All employees in the vicinity to be trained to recognise and report damage, any abnormal incident or potential hazards.
  - No charging in wet or damp conditions to prevent electrocution.
  - Ensure the charging connector is fully and securely plugged into the bus before initiating charging session.

## 6.4. Component 4: Operating Environment

An effective operating environment is essential for safe and efficient functioning of the EBES and delivery of acceptable quality and safe commuter services. This includes strategic route and operations planning that ensures vehicle and the crew readiness, aligns with the vehicle range, identifies hazard prone areas enroute and institutes effective mitigation measures. This also envisages strategic coordination with emergency services such as nearby fire stations, ambulances and health services, traffic police and the Operator Control Room for rapid response in case of incidents. This necessarily envisages availability and implementation of detailed Standard Operating Procedures (SOPs) to enhance passenger safety and system reliability. Further, to ensure preparedness and consistency across the transit system, these SOPs need to, inter-alia, cover emergency protocols, incident response mechanism and communication channels, safe passenger evacuation, affected asset isolation and other road users safety.

## *A. Planning & Design Recommendations*

An effective operating environment for e-bus operations, planning and service delivery recommendations aim to ensure safe, resilient, and uninterrupted e-bus operations under diverse conditions en-route. This section outlines integrated measures for route structuring, operations planning and real-time monitoring, passengers and other road users safety besides multi-agency coordination to mitigate operational risk by effectively responding to emergencies due to electrical, thermal, water, cyber and structural hazards.

### I. Electrical Safety

*Table 33 Stakeholder-Specific Electrical Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **ELECTRICAL SAFETY** | | |
| **1.** | Secure Charger Installation | Charging system Provider; Operations/ Technical Team |
| **2.** | Electrical Hazard Signage display | Charging system Provider; Depot Manager |

***Planning Recommendations***

- **Secure Charger Installation:** Provide secure and disaster resistant installation of en-route fast chargers, complete with fencing, hazard signages and lockable connector ports.
- **Electrical Hazard Signage display:** Display clear electrical hazards signages at the bus stations and terminals, charger access zones, and at crew layover locations for public and crew awareness and safety communications.

### II. Thermal Safety

***Planning Recommendations***

*Table 34 Stakeholder-Specific Thermal Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **THERMAL SAFETY** | | |
| **1.** | Maintain a Fire Station Roster | Depot Management & Workshop System; Charging system Provider |
| **2.** | Implementation of Heatwave Work Protocols | Depot Management & Workshop System; Charging system Provider |
| **3.** | Provision for Automated AC Controls | Procurement Team; OEM |

| S.N. | Activities | Responsibility |
|---|---|---|
| 4. | Use of Ergonomic Driver Seating | Procurement Team, OEM |
| 5. | Provision of Backup Cabin Ventilation | Procurement Team, OEM |

- **Maintain a Fire Station Roster:** In view of higher possibility of fire hazards during heat wave, maintain an updated roster of nearby fire stations, including distance and estimated response time, mapped by route for quick reference by depot staff.
- **Implementation of Heatwave Work Protocols:** Implement heatwave work protocols by limiting shift duration, enforcing mandatory rest breaks and minimising e-bus charging during heatwaves.
- **Provision for Automated AC Controls:** Provide automatic AC control and insulated cabin curtains
- **Use of Ergonomic Driver Seating:** Use ergonomically designed seating, optimally ventilated and thermally insulated driver cabin.
- **Provision of Backup Cabin Ventilation:** Provide for appropriately mounted fans in driver cabin and the salon area, for use when AC fails.

## III. Water Protection

### *Planning Recommendations*

*Table 35 Stakeholder-Specific Water Protection Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **WATER PROTECTION** | | |
| 1. | Installation of Onboard Water Sensors | Procurement Team, OEM |
| 2. | IoT based Real-Time Flood Monitoring | OEM, Depot & Central Workshop System |
| 3. | Identification of Safe Parking Zones | Operations/ Technical Team |
| 4. | Establish Rainfall Suspension Thresholds | Operations/ Technical Team |
| 5. | Obtain Early Warning Alerts | Safety Officer, Depot & Central Workshop System |
| 6. | Flood-Prone Route Mapping | Operations/ Technical Team |
| 7. | Safe Water Wading | Drivers - Conductors |
| 8. | Saltwater Exposure Avoidance | Drivers - Conductors |
| 9. | Pre-Storm Bus Positioning | Drivers - Conductors |
| 10. | Under the tree Parking Avoidance | Drivers - Conductors |
| 11. | Follow Electrical Hazard Clearance | Drivers - Conductors |
| 12. | Maintain speed limits while driving through Water | Drivers - Conductors |

- **Installation of Onboard Water Sensors:** Install water level sensors in e-buses to detect excessive/ dangerous water levels en-route and to provide real-time alerts to the driver.

- **IoT based Real-Time Flood Monitoring:** Utilise real-time weather alerts, Internet of Things (IoT)-based flood detection and monitoring system, and GIS mapping to monitor vulnerable zones.
- **Identification of Safe Parking Zones:** Identify and map safe parking zones for vehicles during flooding or heavy rainfall.
- **Establish Rainfall Suspension Thresholds:** Establish rainfall thresholds for suspension of e-bus services in flood-prone corridors by the Depot Management.
- **Obtain Early Warning Alerts:** Obtain early warning alerts from IMD, local weather station data or water level sensors at key bus stops, depots/ terminal, and low-lying road segments to support route re-planning, diversion and curtailment during heavy rainfall or floods.
- **Flood-Prone Route Mapping:** Identify flood-prone routes using GIS-based flood maps and historical rainfall data and pre-plan alternative routes to minimise operational disruptions.
- **Safe Water Wading:** Avoid routes with water levels exceeding safe wading limits, normally half of vehicle tyre height on short stretches of the routes. Negotiate even such stretches at minimum vehicular speeds (as with higher speeds on such water-logged stretches, friction between the wheels and the road surface reduces significantly rendering vehicular control in-effective).
- **Saltwater Exposure Avoidance:** Avoid water-logged stretches particularly those with saltwater, as they pose risks of corrosion, short circuiting, and potential e-bus fires.
- **Pre-Storm Bus Positioning:** On pre-detection of storms, pre-position buses under flyovers or in sheltered parking before arrival of storms.
- **Under the Tree Parking Avoidance:** During storms and heavy rains, avoid parking buses under trees, which can attract thunderstorm and lightening, and damage buses due to falling tree or heavy tree branches.
- **Follow Electrical Hazard Clearance:** Steer clear e-buses of potential electrical hazards which may be caused due to power lines, poles and other metal structures in case of storms.
- **Maintain speed limits while driving through Water:** When driving through waterlogged roads, let vehicle speed not exceed 15 km/h. On roads with large water ripples or splashes, limit vehicle speed to less than 5 km/h.

## IV. Cyber Security

### *Planning Recommendations*

*Table 36 Stakeholder-Specific Cyber Security Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **CYBER SECURITY** | | |
| **1.** | Installation of Secure Communication Protocols | OEM, ITS Team |
| **2.** | Install Network Security Controls | OEM, ITS Team |
| **3.** | Provision for GPS Spoofing Protection | OEM, ITS Team |
| **4.** | Passenger Digital Awareness | Capacity Building Team |

- **Installation of Secure Communication Protocols:** Install and use authenticated and encrypted protocols for vehicle-to-infrastructure and vehicle-to-vehicle communication.
- **Install Network Security Controls:** Install network security control mainly comprising of firewalls, intrusion detection systems, and undertake regular security audits.
- **Provision for GPS Spoofing Protection:** Provide anti-spoofing measures in navigation systems for GPS Spoofing Prevention
- **Passenger Digital Awareness:** Educate passengers on safe use of onboard digital systems for public awareness.

## V. Structural Safety

### *Planning Recommendations*

*Table 37 Stakeholder-Specific Structural Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **STRUCTURAL SAFETY** | | |
| 1. | Safe Towing Procedure | OEM |
| 2. | Route Vulnerability Mapping | Operations/ Technical Team |
| 3. | Weather-Based Suspension | Safety Officer; Operations/ Technical Team |
| 4. | Route Diversions during Protest | Safety Officer; Operations/ Technical Team |
| 5. | Traffic Safety Measures | Drivers - Conductors; First Responders |
| 6. | Audible Vehicle Alerts | OEM |
| 7. | Law Enforcement Coordination | Safety Officer |

- **Safe Towing Procedure:** If an e-bus is towed with its rear or drive wheels on the ground, remove driveshaft to stop drive motor input shaft from rotating. This helps avoid damage to the motor and inverter, which are costly to replace.
- **Route Vulnerability Mapping:** Pre-identify routes with vulnerability of e-buses to trees, hoardings, and construction.
- **Weather-Based Suspension:** Suspend services on the specific routes based on city weather alerts.
- **Route Diversions during Protest:** Implement route diversion plans from protest affected areas.
- **Traffic Safety Measures:** Implement traffic safety measures, like bus only lanes, speed limits, speed cooling measures, speed breakers, zebra crossings for pedestrians, accident prone areas, blind turns, schools ahead, or clear signages to avoid the risk of collisions, with the help of Traffic Police.
- **Audible Vehicle Alerts:** Install audible cues to help driver monitor acceleration in e-bus, ensuring that the silent vehicle remain detectable by the road users to avoid accidents.

- **Law Enforcement Coordination:** Establish mutual aid protocols with local law enforcement for rapid response. Coordinate with IMD/ SDMA for early warnings.

## VI. General Safety Measures

### *Planning Recommendations*

*Table 38 Stakeholder-Specific Common Safety Mitigation Measures*

| S.N. | Activities | Responsibility |
|---|---|---|
| **GENERAL SAFETY MEASURES PLANS** | | |
| 1. | Hazard Specific GIS Inventory | Depot Management; First Responders |
| 2. | Safe Zone Information | Safety Officer; Drivers - Conductors; Operator's Control Room |
| 3. | Dynamic Route Management | Depot Management; Operations/ Technical Team |
| 4. | Microclimate Monitoring | Safety Officer; Operations/ Technical Team |
| 5. | Continuous Data Monitoring | Operator's Control Room; Operations/ Technical Team |
| 6. | Accident Coordination Protocols | Operations/ Technical Team; Drivers - Conductors; First Responders |
| 7. | Technology Audit Cycle | Safety Officer; Depot & Central Workshop System |
| 8. | Offline Operations Capability | OEM; Depot & Central Workshop System |
| 9. | Passenger safety | Capacity Building Team; Drivers - Conductors; OEM |
| 10. | Coordination and Communication channel | Safety Officer; Operations/ Technical Team; Operator's Control Room; Drivers – Conductors/ Bus Crew |

- **Hazard specific GIS Inventory:** Create a GIS based inventory mapping for all the critical points where past hazards have occurred.
- **Safe Zone Information:** Plan for and ensure drivers and conductors have easy access to information on designated safe zones along each route.
- **Dynamic Route Management:** Plan for real time route behaviour management system to use real-time early warnings related to monitoring weather conditions and dynamically adjusting the routes as needed.
- **Microclimate Monitoring:** Install Automated Weather Station (AWS) at terminals and bus stops in hazard prone areas to monitor microclimates where IMD's AWS coverage is absent. Deploy seismic sensors where appropriate.
- **Continuous Data Monitoring:** Install data monitoring system and continuously monitor sensor data to facilitate timely and informed decision making during hazardous events.
- **Accident Coordination Protocols:** Develop detailed accident coordination protocol to effectively coordinate with traffic police in case of accidents.

- **Technology Audit Cycle:** Establish technological audit and upgrade protocols every 2-3 years.
- **Offline Operations Capability:** To safeguard from technological failure, maintain offline operating capability as well.

***Passenger safety***

- **Driver Safety Training:** Develop crew training modules and train drivers on safe water wading limits and conductors on evacuation protocols and basic first aid.
- **Emergency Systems Readiness:** Install requisite emergency readiness system and ensure that emergency lighting, warning signals and fire detection and suppression systems are operational and can be activated when needed.
- **Emergency Information Display:** Display easy-to-understand emergency procedure graphics inside the bus at accessible locations.
- **Inclusive Alarm Systems:** Install both visual and audible alarm system to ensure that the alerts are identified by passengers even with visual or hearing impairments.

***Coordination and Communication channel***

- **Emergency Coordination Framework:** Establish clear coordination mechanisms and response procedures with emergency services, local authorities, and other relevant stakeholders for effective incident response.
- **Multi-Agency Alert Tracking:** Continuously track the hazardous alerts and updates from the IMD, UDMA, DISCOM, Smart City, traffic police and other relevant stakeholders for making informed decisions.
- **Passenger Information Systems (PIS):** Install on-board PIS including Public Address System (PAS) to keep passengers informed of potential delays, diversions, or cancellations through multiple channels such as social media, mobile apps, and public address systems.

## *B. Maintenance Activities*

Various systems and sub-systems pertaining to operating environment call for timely completion of maintenance activities and applicable refresher training programmes to ensure safe service continuity under routine conditions as well as during seasonal disruptions such as heavy rainfall and route disturbances. Successful implementation requires clearly defined mitigation actions by relevant stakeholders, as detailed in the following table to support enforcement and compliance.

*Table 39 Stakeholder-Specific Maintenance Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| **1.** | Regular Refresher Training | OEM; Capacity Building Team; Depot & Central Workshop System; First Responders |
| **2.** | Seasonal Mock Drills | Capacity Building Team; Safety Officer; First Responders |

All maintenance activities for systems and sub-systems of operating environment be meticulously carried out as per respective OEM/ related agency prescribed schedules by adequately trained staff. Some of the maintenance/ capacity building activities are discussed here-under:

- **Regular Refresher Training:** Regular refresher courses for the involved staff including drivers, covering not only driving skills but also the operational and maintenance skills wrt capacity building team periodically. Additionally, eyesight tests, hearing other and health check-ups, normally once every quarterly, be undertaken for the crew particularly the drivers.
- **Seasonal Mock Drills:** Along with necessary maintenance activities and seasonal refresher training programmes, conduct mock drills simulating heavy rainfall, route disruptions and other hazards applicable to operating environment.

## C. Inspection

Inspection activities related to operating environment focus on proactively assessing route conditions and adapting operations to changing external factors. Successful implementation requires clearly defined mitigation actions by relevant stakeholders, as detailed in the following table to support enforcement and compliance.

*Table 40 Stakeholder-Specific Inspection Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Periodic Route Inspection | Depot Management; Safety Officer; Operations/ Technical Team |
| 2. | Weather-Based Route Updates | Safety Officer; Operations/ Technical Team |

The following safety-critical systems and components shall be mandatorily checked during periodic inspections.

- **Periodic Route Inspection:** Periodically inspect and verify the physical condition on e-bus routes wrt road condition, accident prone areas marking, signages, condition of large trees, water logging during rains, and other items likely to affect Operating Environment and operational safety protocols.
- **Weather-Based Route Updates:** Update e-bus routes wrt different parameters affecting Operating Environment e-buses basis weather alerts.

## D. Training

The capacity building activities pertaining to Operating Environment are aimed at building driver and crew competence to safely operate e-buses under diverse and challenging conditions. These activities combine structured training, practical simulations, route familiarisation, and inter-agency coordination to ensure that the crew can effectively monitor vehicle systems, respond quickly and effectively to alarms/ alerts, manage emergencies, and maintain safety while operating in hazardous environments. Effective implementation requires targeted mitigation actions by relevant stakeholders, generally as outlined in the following table for enforcement and compliance.

*Table 41 Stakeholder-Specific Training Activities*

| S.N. | Activities | Responsibility |
|---|---|---|
| 1. | Dual Training Programme | OEM; Capacity Building Team; Procurement Team |
| 2. | Simulator-Based Training | Capacity Building Team; Drivers - Conductors |
| 3. | Route Familiarisation training | Capacity Building Team; Drivers - Conductors |

| S.N. | Activities | Responsibility | |
|---|---|---|---|
| 4. | Dashboard Monitoring Skills | Capacity Building Team | Drivers - Conductors |
| 5. | Immediate Alarm Response | Capacity Building Team | Drivers - Conductors |
| 6. | Emergency Evacuation Training | Capacity Building Team | Drivers - Conductors |
| 7. | Hazardous Driving Skills | Capacity Building Team | Drivers - Conductors |
| 8. | Inter-Agency SOP Development: | Safety Officer | First Responders |
| 9. | High-Voltage Safety Training for Crew | Capacity Building Team | Drivers - Conductors |

Various training activities designed for drivers, crew, and other relevant personnel, are as follows:

- **Dual Training Programme:** Under Gross Cost Contracts, implement dual training programmes i.e, basic professional training and general route operations by the private operator and advanced training related to different system and sub-systems pertaining to Operating Environment, particularly to handling emergencies en-route by STUs and OEMS.
- **Simulator-Based Training:** Mandate computer and simulator-based training for all drivers. It will replicate real-world conditions such as urban traffic, adverse weather, and emergency scenarios, enabling safe, hands-on learning without risking lives or assets.
- **Route Familiarisation training:** Under the supervision of the Capacity Building team, train bus crew on route familiarisation, generally involving routes conditions, operating environment en-route, live traffic situation and traffic rules for about a week using an e-bus before deploying them on regular revenue earning route schedules.
- **Dashboard Monitoring Skills:** Train drivers in upgrading their to appreciate dash-board and other signs and signals to always understand and monitor dashboard indicator lights (Tell-Tale Lamps/ signs) and correctly interpret dashboard fault codes for taking necessary actions.
- **Immediate Alarm Response:** Train onboard crew to immediately respond to any visual or audible fault alarms during operations.
- **Emergency Evacuation Training:** Train crew on protocols pertaining to safe evacuation of passengers, system shutdown procedures in case of fire, floods, storms or water ingress, and other emergency scenarios.
- **Hazardous Driving Skills:** Train drivers on safe driving techniques through waterlogged zones and other hazardous situations.
- **Inter-Agency SOP Development:** Coordinate with local disaster management authorities, Fire Fighting Agencies and Municipal bodies to develop joint SOPs for flood response, communications protocols, firefighting and passenger evacuation.
- **High-Voltage Safety Training for Crew on:**
  - Recognizing HV warnings and dashboard alerts
  - Safely isolating the HV system in emergencies
  - Reporting electrical faults encountered enroute via SCADA or radio.

# 7. DURING DISASTER STRATEGIES

This chapter outlines emergency response protocols and coordination measures to be followed when a disaster occurs, covering all hazards natural, technological, and human-induced hazards (Floods, Heavy rain, Cyclone, Earthquake, Landslide, Grid Instability, Battery Failure, Protest/ Vandalism, Traffic Accident and Human Negligence). It focuses on safeguarding life, protecting critical assets, and ensuring operational continuity across the four core components of the EBES - fleet, depot, charging infrastructure, and operating environment. Hazard-specific protocols and corresponding responsibility mapping are provided to guide rapid and coordinated action.

## 7.1. Communication Protocol

A robust communication protocol is the backbone of disaster resilience in electric bus operations. It ensures timely information flow, clear responsibilities, and coordinated emergency actions during natural hazards, technological failures, and human-induced risks.

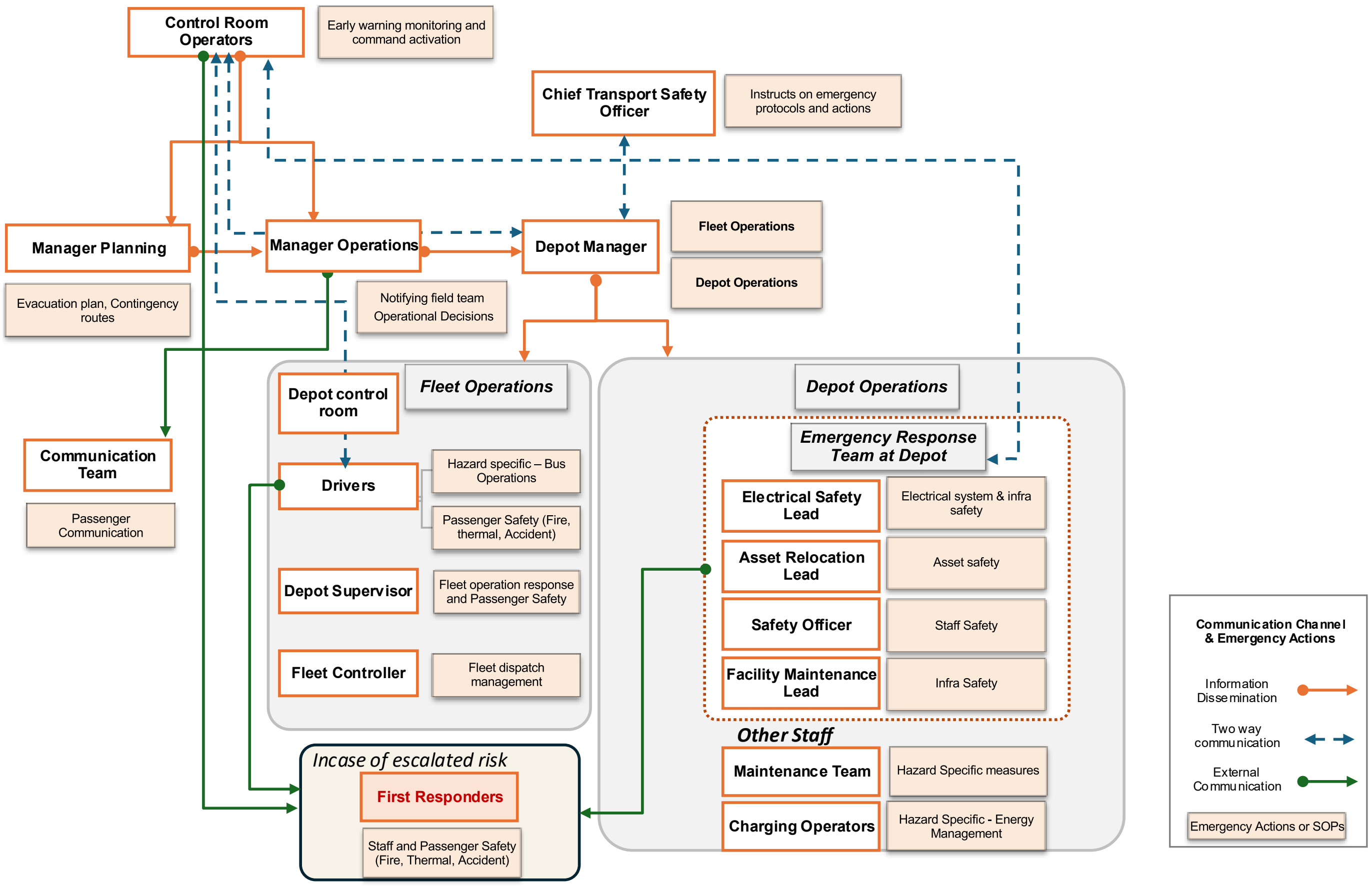


*Exhibit 71 Communication Protocol Channel*

The communication channel for disaster management in an electric bus ecosystem is designed to ensure rapid, reliable, and multi-directional information flow between all stakeholders during emergencies.

### 1. Central Command

- Control Room acts as the primary hub for monitoring hazards, issuing alerts, and activating emergency protocols. Where a city already has a Central Command Centre, the same may be leveraged for these functions.

- It communicates with Manager Operations and Manager Planning at Head Office for strategic decisions and evacuation planning.
- Communicates with field staff (drivers, depot control room etc) for emergency actions and timely information dissemination.

**2. Internal Communication**

Depot Managers, Fleet Controllers, and Drivers receive instructions through:

- ITMS (Integrated Transport Management System) for real-time route updates.
- Radio/VHF networks for voice communication when digital systems fail.
- Secure messaging platforms for operational updates and confirmations.

**3. External Communication**

- Passengers are informed via:
  - Mobile apps and SMS alerts for rerouting and service disruptions.
  - Public announcements at depots and bus stops.
- Emergency Services (fire, medical, police) are contacted through dedicated lines for immediate assistance.

**4. Two-Way Feedback**

- Field teams provide situational updates to the Control Room for dynamic decision-making.
- Drivers confirm rerouting instructions and passenger safety status.

## 7.2. Response Protocols - Natural, Technological and Human Induced Hazards

Electric bus operations face critical risks during disasters such as natural, technological, and human-induced that demand immediate, structured response to protect passengers, staff, and assets.

- Natural Hazards (floods, earthquakes, heatwaves): Require route checks, emergency shutdowns, and hazard control.
- Technological Hazards (grid failure, battery issues, cyber threats): Demand HV isolation, secure operations, and predictive maintenance.
- Human-Induced Hazards (protests, accidents, management gaps): Need hazard detection, safe evacuation, and strong communication.

During a disaster, the swift activation of fleet and depot protocols, emergency SOPs, and coordination with external agencies becomes essential to safeguard lives and ensure continuity of operations. In this framework, the Chief Transport Safety Officer (CTSO) provides overall oversight of safety, disaster preparedness, and resilience across the city's EBES. The CTSO develops and updates the city-specific SOPs aligned with local risk profiles, while ensuring compliance with applicable safety standards. Furthermore, the role extends to leading emergency response during incidents such as fires, floods, or cyberattacks, coordinating on-ground response teams and strengthening preparedness through regular training programmes, mock drills, and structured safety inductions for staff. Accordingly, this section presents a structured step-by-step framework outlining actions, responsibilities, and activation triggers to facilitate safe evacuation, systematic damage assessment and operational recovery.

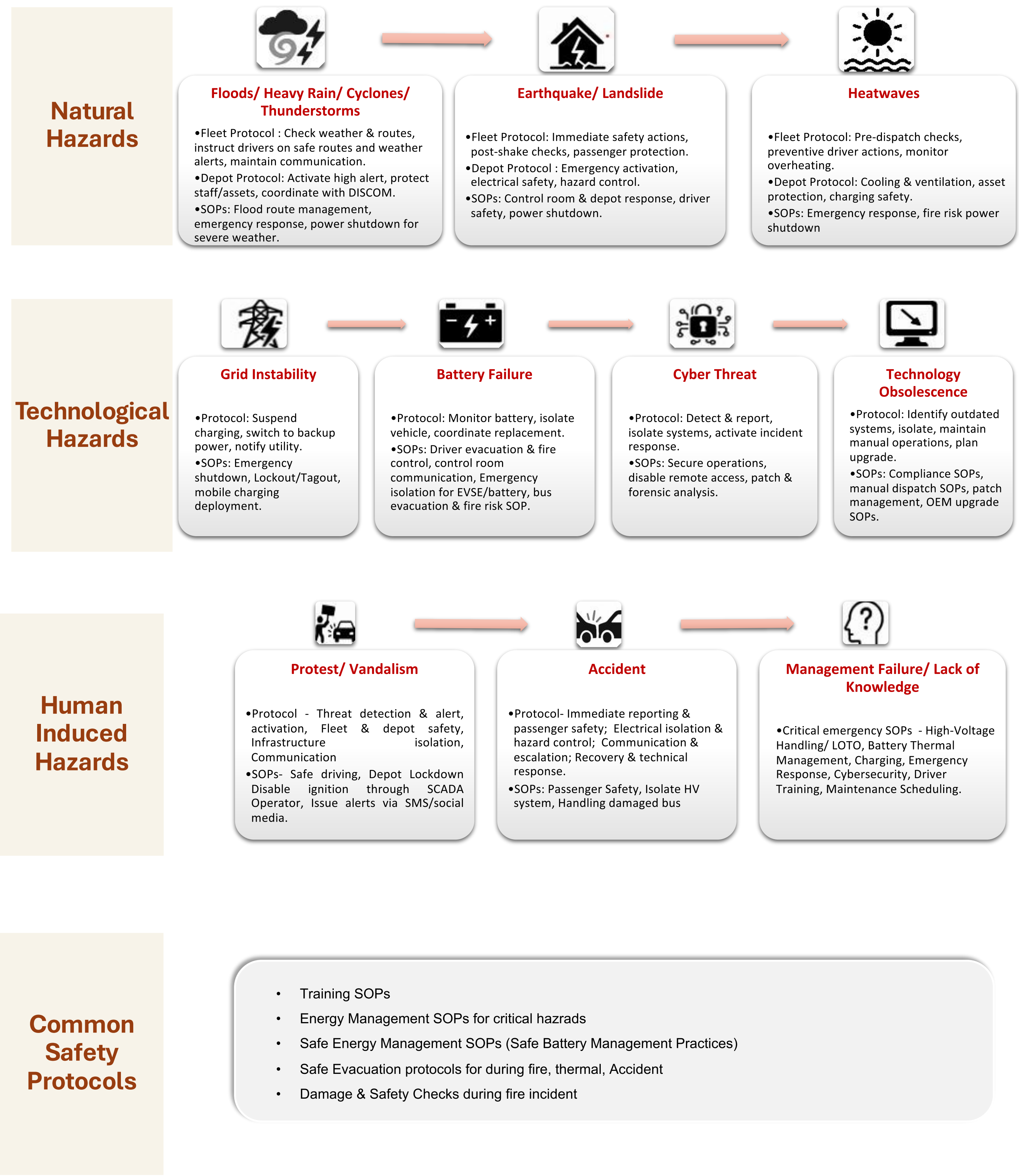


*Exhibit 72 Response Protocol - Natural, Technological, Human Induced and Common Safety Protocols*

***Detailed Emergency Protocols and SOPs – Natural Hazard***

# FLOOD/ CYCLONE/ HEAVY RAINS/ THUNDERSTORM

## FLEET OPERATIONS PROTOCOL

**Trigger Points**
- Water on road exceeds curb level
- Road closures or diversions
- Visibility < 100 meters.

**Responsibility**: Depot Manager, Communication Team, Depot Supervisors, Driver

### A. PRE-DEPARTURE CHECKS

**Responsibility:** Depot Manager

**Weather & Route Assessment**
- ✅ Check official weather alerts.
- ✅ Confirm route safety with Control Room.
- ✅ Avoid flood-prone stretches.

**Responsibility:** Depot Supervisors

**Vehicle Readiness**
- ✅ Check: brakes, lights, wipers, horn, defoggers.
- ✅ Emergency kit: torch, first aid, reflective triangle, fire extinguisher.
- ✅ Tyres: good tread depth.

### B. DRIVER INSTRUCTIONS

**Responsibility:** Depot Manager

**While Driving**

🚫 Avoid water deeper than half tyre height or if sensor alerts (650 mm) or beyond the vehicle's ground clearance, whichever is lower.

🚫 **Avoid –** Bridges/ underpasses with water flowing over and High stream flow areas.

Reduce speed near waterlogged areas.

⚠ Maintain steady throttle; avoid sudden braking/acceleration.

Keep emergency contacts ready (Control Room, Police, Fire, Disaster Management Authority).

### C. COMMUNICATION

**Responsibility:** Communication Team

Announce delays/diversions suspended operations via: Onboard PA system; Mobile apps

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Control Room

**Fleet Operation SOPs for Control Room**
- Flag flood-prone routes and inform drivers & depot managers immediately.
- Identify safe alternate routes using ITMS and traffic advisories.
- Communicate re-routing instructions to driver and confirm acknowledgment

**Responsibility:** Depot Manager

**Fleet Operation SOPs for Depot Manager**
- Suspend all bus operations on flood-affected routes immediately.
- Coordinate with ECC for safe rerouting and alternate route clearance.
- Alert drivers about waterlogged zones and underpasses to avoid.
- Deploy relief buses to evacuate passengers from stranded vehicles.
- Maintain continuous communication with Control Room for updates.
- Track fleet positions via GPS and confirm driver safety.
- Log all incidents (bus ID, location, passenger count) in emergency register.
- Quarantine buses exposed to floodwater for inspection before redeployment.

**Responsibility:** Driver

**Fleet Operation SOPs for Driver**
- Avoid flooded roads and divert rout as per instruction from control room.
- Avoid halting in deep water zones; stop at elevated safe points if necessary.
- Do NOT enter water deeper than half the tyre height or beyond the vehicle's ground clearance, whichever is lower
- Avoid sudden braking or acceleration to prevent water splash into components.
- If caught in rising water, stop and evacuate passengers to higher ground if safe.
- Follow instructions from Control Room or depot manager.

# FLOOD/ CYCLONE/ HEAVY RAINS/ THUNDERSTORM

## DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- Water Ingress
- Electrical Fault Alerts
- Structural Damage
- Lightning Events

**Responsibility:** Depot Manager | Control Room | Electrical Engineers | Charging Operators | Fleet Supervisor

### A. INCIDENT ACTIVATION

**Responsibility:** Depot Manager

✅ Trigger **Flood Response Protocol when high-alert warning or visible flooding signs appear.**

✅ Activate **Emergency Response Team (ERT)**:
- **Electrical Safety Lead**
- **Asset Relocation Lead (Fleet Supervisor)**
- **Logistics & Communication Lead**

### B. STAFF SAFETY & ASSET PROTECTION

**Responsibility:** Fleet Supervisor | Electrical Engineers | Charging Operators

✅ Disconnect power to **charging units and depot electrical systems**.

Move buses & staff to **pre-identified flood-safe zones**.

Deploy **portable pumps and sandbags** to redirect water away from critical areas.

Ensure all staff remain in designated safe zones and follow safety protocols.

### C. COMMUNICATION

**Responsibility:** Communication Lead

Notify **DISCOM** for emergency power disconnection.

Maintain continuous communication with Flood Control /Disaster Management Authority, Fire Safety Department etc.

Update **Control Room** with real-time depot status and service impact.

**Responsibility:** Electrical Engineers | Charging Operators

#### Charging Infrastructure Isolation SOP for Flood/Cyclone
- Before Securing, stop all charging sessions, wear PPE and inspect cables
- Inform control room on emergency isolation.
- Activate emergency stop buttons on charging units.
- Isolate the main power supply from the electrical panel.
- Inform emergency response team and control room immediately.
- Do not attempt to restart systems until cleared by safety officer.
- Place warning signs with barriers Restrict access to exposed areas for safety.
- Conduct a visual inspection to confirm all systems are safely shut down.
- Record shutdown status in the operations logbook and report any anomalies.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Manager

#### Depot Manager Emergency Response SOP for Severe Weather
- Stop all bus entry/exit immediately. Move buses to safe, elevated zones.
- Suspend charging & maintenance and Do NOT attempt to restart any charging or power equipment without clearance.
- Relocate spare batteries and water sensitive components to dry storage.
- Secure critical records, hazardous materials, and workshops.
- Evacuate staff to shelters and maintain emergency communication.

**Responsibility:** Electrical Engineers | Charging Operators

#### Safe Power Shutdown SOP for Extreme Weather Events
- Ensure all personnel are clear of high-voltage areas before shutdown.
- Use appropriate PPE (Personal Protective Equipment) during the procedure.
- Begin shutdown sequence from non-critical systems to critical systems.
- Disconnect charging stations and isolate battery banks (if any).
- Power down depot lighting, HVAC, and auxiliary systems.
- Shut down main power supply using the master control panel.
- Monitor for any abnormal sounds, smells, or heat signatures.
- Keep fire suppression systems on standby.
- Log the shutdown time, reason, and personnel involved.

# EARTHQUAKE/ LANDSLIDE

## FLEET OPERATIONS PROTOCOL

**Trigger Points**
- Ground shaking felt
- Road cracks or bridge damage
- Emergency alerts received
- Passenger panic or injury

**Responsibility:** Depot Manager | Control Room | Depot Supervisors | Driver

### A. IMMEDIATE ACTIONS DURING EARTHQUAKE / LANDSLIDE

**Responsibility:** Driver

🚫 Stop the vehicle safely away from bridges, flyovers, tunnels, trees, and unstable structures.
🚧 Engage parking brake and keep passengers inside until shaking stops.
✅ Calm passengers and provide instructions to remain seated.

### B. POST-SHAKING SAFETY CHECK

**Responsibility:** Driver

🩺 Check for injuries among passengers and provide first aid if possible.
🔍 Inspect the bus for visible damage (tires, suspension, electrical systems).
📢 Report status to Depot Manager immediately.

### C. OPERATIONAL COORDINATION

**Responsibility:** Depot Manager

📍 Track all vehicles, confirm driver safety and share safe routes with drivers.
⛔ Suspend all non-essential trips immediately & Redirect buses to designated safe zones or emergency shelters.
📞 Use backup communication systems (radio, satellite phones) if needed.
🤝 Coordinate with emergency services/ Disaster Management Authority for assistance.

### D. PASSENGER SAFETY & SUPPORT

**Responsibility:** Communication Team

📢 Provide clear instructions to passengers.
🚶 Assist passengers with evacuation if necessary (move to open safe areas).
👵 Prioritize vulnerable passengers during evacuation.
🧃 Provide water and basic aid if available.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Control Room

**Control Room Protocol for Fleet Operations**
- Maintain communication with all drivers and depot managers.
- Share safe routes and shelter locations.
- Track vehicle positions and prioritize rescue if needed.

**Responsibility:** Depot Manager

**Depot Manager SOP for Emergency Response**
- Instruct drivers on stop buses in safe open areas after shaking stops keep doors open for quick evacuation.
- Account for all vehicles and drivers via GPS/manual check-ins.
- Hold dispatch until roads and depots are confirmed safe; inspect buses before redeployment.
- Maintain contact with Control Room/ICCC; prepare relief buses for stranded passengers.
- Coordinate with ECC for damage assessment and route clearance before resuming.

**Responsibility:** Driver

**Driver SOP for Safety and Passenger Protection**
- Stop the bus in an open, safe area away from bridges, flyovers, and slopes.
- Apply parking brake; calm and keep passengers inside until shaking stops.
- Keep doors open for quick evacuation if unsafe inside and evacuate passengers to open spaces away from poles and glass.
- After earthquake/ landslide check for injuries; provide first aid if possible.
- Contact emergency services (fire, medical) if injuries or hazards exist. Report status to Control Room immediately with situational update
- Follow rerouting or evacuation instructions from Depot Manager/Control Room

# EARTHQUAKE/ LANDSLIDE

## DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- **Earthquake:** Tremors felt or official seismic alert issued.
- **Landslide:** Visible soil movement, cracks near slopes, or warnings.

**Responsibility:** Depot Manager | Control Room | Emergency Response Team | Maintenance Team | Safety Officer

### A. EMERGENCY ACTIVATION

**Responsibility:** Depot Manager

Activate **Emergency Response Team (ERT)** and assign roles:
**Electrical Safety lead** | **Asset Relocation lead** | **Communication**

### B. SAFETY PROTOCOLS

**Responsibility:** Safety Officer

**Staff Safety**
- During tremors: Take cover under sturdy furniture or move to open space.
- After tremors: Evacuate staff to **assembly points** away from buildings, poles, buses.
- For landslide: Move staff to **stable uphill zones**; avoid slopes.
- Keep staff away from high -voltage zones, exposed wires or damaged batteries

**Responsibility:** Electrical Safety Lead

**Electrical Safety**
- Turn off main power supply immediately.
- Stop charging operations, disconnect connectors safely (after shaking stops).
- Do not move batteries during shaking.
- Barricade charging area until inspected by DISCOM/Electrical Safety Officer.
- If safe, use **main breaker for emergency power shutdown.**

**Responsibility:** Safety Officer

**Staff and Asset Safety SOPs for Safety Officer**
- Monitor the situation from the Emergency Control Room (if safe).
- Trigger emergency alarms if not already activated.
- Ensure emergency lighting is operational.
- Move away staff from battery banks and energy storage systems.
- Begin headcount once shaking stops and evacuation begins.
- Assist in guiding personnel to safe zones once shaking stops.
- Monitor for secondary hazards like fire, gas leaks, or structural damage

### C. HAZARD CONTROL

**Responsibility:** Maintenance Team

- Barricade cracked zones or slope failure areas
- Deploy sandbags/barriers to protect electrical rooms from mud/water ingress.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Manager

**Depot Manager Emergency Response SOP**
- Activate Emergency Response Protocol.
- Announce “Take Cover” via PA system (if working).
- Instruct to stop all bus movement; park in open areas away from structures/slopes.
- Instruct drivers via radio: Stop buses in safe spots and stay inside until shaking stops.
- Suspend all dispatches immediately.
- Do not evacuate during shaking unless there’s fire or collapse risk.
- Maintain radio contact with Safety Officer and Security Team.

**Responsibility:** Electrical Safety Lead

**SOPs for Emergency Power Shutdown procedure**
- Access main electrical room or emergency power panel.
- Wear PPE (insulated gloves, boots)Locate emergency shutdown switch (marked red or labeled).
- Activate shutdown (turn main breaker OFF).
- Check indicator lights confirm power OFF.
- Communicate status to Depot Manager and Control Room.
- Lock electrical room and post “POWER OFF – DO NOT OPERATE” signage.
- Wait for clearance before restoring power (after inspection).

# HEATWAVES/ EXTREME TEMPERATURE

## FLEET OPERATIONS PROTOCOL

**Trigger Points**
- High Battery Temp Warning (BMS)
- HVAC or Cooling Failure Alert
- Voltage/Current Fluctuation Warning
- Thermal Alarm (Battery/Electrical System)

**Responsibility:** Depot Manager | Control Room | Depot Supervisors | Driver

### A. PRE-OPERATION CHECKS (BEFORE DISPATCH)

**Responsibility:** Depot Supervisors

- ✅ Conduct battery diagnostics using BMS temperature data.
- ✅ Verify coolant levels and battery thermal management systems.
- ✅ Check tyre inflation (heat can cause blowouts).
- ✅ Ensure HVAC systems are fully functional for passenger comfort.
- ✅ Confirm dashboard indicators and signaling systems are operational.
- ✅ Ensure availability of fire extinguishers.

### B. PREVENTIVE ACTIONS

**Responsibility:** Driver

- Report unusual smells, performance drops, or warning lights immediately.
- Carry emergency water supplies for crew and passengers.
- Optimize speed to reduce battery strain and overheating risk.
- Check availability of first aid kits in buses.

### C. MONITORING & REPORTING

**Responsibility:** Driver

- Check dashboard for HV battery overheating warnings.
- Inspect tire pressure (heat can cause blowouts).
- Report any smoke, odor, or abnormal heat from battery or electrical systems.
- Inform Control Room of critical issues-

### D. OPERATIONS COORDINATION

**Responsibility:** Depot Manager

- Track all vehicles and prioritize routes with shaded stops.
- Suspend or reschedule trips during peak heat hours if risk is high.
- Ensure bus cooling systems and depot ventilation are functional.
- Coordinate with Control Room for rerouting and passenger safety.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Control Room

**Fleet Operation SOPs for Control Room**
- Maintain constant communication with drivers and depot managers.
- Share heat alerts and safe parking locations.
- Track battery temperature data and prioritize buses showing alerts.

**Responsibility:** Depot Manager

**Fleet Operation SOPs for Depot Manager**
- Instruct drivers to park in shaded areas and keep ventilation.
- Account for all vehicles via GPS and monitor battery health.
- Suspend or reschedule trips during peak heat hours if risk is high.
- Ensure bus cooling systems and depot ventilation are functional.
- Coordinate with ECC for technical support if overheating occurs.
- Prepare standby buses for redeployment if any bus is grounded..

**Responsibility:** Driver

**Fleet Operation SOPs for Driver**
- Report unusual smells, performance drops, or warning lights immediately.
- Optimize speed to reduce battery strain and overheating risk.

**If Temperature Alert Triggers Enroute:**
- Stop bus in safe, shaded area if overheating warning appears.
- Switch HVAC to maximum cooling if battery allows.
- Inform Control Room immediately with location and passenger load and take action basis the guidance from control room.
- Keep passengers calm and hydrated. Evacuate passengers if smoke or severe overheating occurs.
- Do not restart bus until cleared by Depot Manager / Control Room.

# HEATWAVES/ EXTREME TEMPERATURE

## DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- **Heatwave Alert** Issued by IMD or local authority.
- **Extreme temperature warnings** (above safe operational limits).

**Responsibility:** Depot Manager; Electrical Safety Lead; Charging Operators; Maintenance Team; Safety Officer

### A. COOLING & VENTILATION

**Responsibility:** Maintenance Team

- Activate additional ventilation systems in parking bays.
- Deploy temporary shading structures or reflective covers over buses.
- Monitor ambient depot temperature; restrict indoor charging if unsafe.

### B. ASSET PROTECTION

**Responsibility:** Electrical Safety Lead

- Activate climate control for battery storage and spare parts.
- Ensure dedicated air-conditioning (AC) systems to maintain temperatures within OEM-specified limits
- Maintain fire safety readiness with extinguishers and heat-triggered alarms.

### C. PRE-CHARGING MEASURES

**Responsibility:** Charging Operators

- Inspect charger cooling systems and ensure ventilation.
- Avoid charging during peak heat; prioritize early morning or night.
- Check connector insulation and cables for heat damage.

### D. MONITORING AND REPORTING

**Responsibility:** Safety Officer

- Monitor battery and charger temperature sensors.
- Initiate emergency power shutdown if overheating risk escalates.
- Avoid contact with damaged or overheated battery units.
- Report status to Depot Manager and Control Room.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Manager

**Depot Operation SOPs for Depot Manager**
- Activate Emergency Response Protocol.
- Announce heat safety instructions via PA system.
- Suspend charging and maintenance during peak heat.
- Relocate buses to shaded parking zones.
- Maintain communication with Safety Officer and Control Room.

**Responsibility:** Charging Operators

**SOPs for Charging Operators**
- Inspect charger cooling systems and ensure ventilation.
- Activate BMS-integrated temperature control to reduce charging rate if battery overheats.
- Maintain thermal monitoring logs during charging sessions.
- Keep chargers out of direct sunlight or use reflective shielding.

**Responsibility:** Electrical Safety Lead

**SOPs for Emergency Power Shutdown procedure if fire risk persist**
- Access main electrical room or emergency power panel.
- Wear PPE (insulated gloves, boots)Locate emergency shutdown switch (marked red or labeled).
- Activate shutdown (turn main breaker OFF).
- Check indicator lights confirm power OFF.
- Communicate status to Depot Manager and Control Room.
- Lock electrical room and post “POWER OFF – DO NOT OPERATE” signage.
- Wait for clearance before restoring power (after inspection).

## Detailed Emergency Protocols and SOPs – Technology Hazard

# GRID INSTABILITY/ GRID FAILURE

## FLEET & DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- Sudden voltage fluctuations, frequency deviations, or grid failure alerts from DISCOM
- Power outage beyond backup capacity

**Responsibility:** Depot Manager | Electrical Safety Lead | EVSE Technician | Maintenance Team | Safety Officer

### A. CHARGING CONTROL

**Responsibility:** Depot Manager

**Suspend EV Charging**
- Monitor grid voltage/frequency via SCADA or EMS.
- If instability is detected, issue command to halt all EVSE operations.
- Inform fleet coordinator about charging suspension.
- Place physical lockout tags on affected chargers if needed.

**Responsibility:** EVSE Technician

**Isolate Faulty EVSE Units**
- Identify chargers showing abnormal current, voltage, or thermal alerts.
- Disconnect from power source and isolate from network.
- Tag units with fault status and log in maintenance system.
- Report to maintenance engineer for inspection.

### B. POWER BACKUP ACTIVATION

**Responsibility:** Electrical Safety Lead

**Switch to Backup Power**
- Assess load requirements for critical systems (control room, fire safety, HVAC).
- Start DG/UPS/BESS systems as per SOP.
- Verify stable output before switching load.
- Monitor fuel/battery levels and runtime capacity.

**Responsibility:** Facility Maintenance Lead

**Verify HVAC and Fire Safety Systems**
- Check operational status of fire alarms, suppression systems, and ventilation.
- Ensure backup power is supplying these systems.
- Manually test alarms and emergency lighting.
- Escalate any failures to safety officer.

### C. COMMUNICATION & ESCALATION

**Responsibility:** Depot Manager

**Notify Utility Provider**
- Contact grid operator or utility helpdesk.
- Share timestamp, nature of instability, and affected systems.
- Request timeline for resolution or load shedding schedule.
- Document communication in incident log.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Manager

**Depot Operation SOPs for Depot Manager**
- Announce "Grid Instability – Standby Mode"
- Suspend all charging operations immediately
- Park buses safely; avoid movement during blackout
- Coordinate with DISCOM for restoration timeline
- Maintain communication with Safety Officer & Electrical Safety Lead
- Inform drivers and control center and alter the service frequency appropriately.
- Reroute buses to alternate charging locations if needed.
- Deploy mobile charging units if available.

**Responsibility:** Electrical Safety Lead

**SOPs for Safety Officer**
- Initiate Emergency Power Shutdown if required
- Follow Lockout/Tagout procedure for faulty circuits
- Switch to backup power (DG/UPS) as per SOP
- Monitor for sparks, overheating, or smoke in panels
- Inform the Control Room
- Document electrical anomalies for post-event analysis

# BATTERY FAILURE

## FLEET OPERATIONS PROTOCOL

**Trigger Points**
- Smoke or sparks from battery compartment.
- Dashboard warning for battery fault or thermal runaway.
- Sudden power loss or inability to accelerate.

**Responsibility:** Depot Manager; Depot Control Room; Depot Supervisors; Driver

### A. BATTERY MONITORING

**Monitor via BMS & Telematics:**

**Responsibility:** Driver

**Driver to Monitor following alerts:**

- Low SOC (< 20%)
- High battery temp (as prescribed by OEM) (> 40°C)
- Battery fault warning
- Charging error
- Voltage drop
- Thermal runaway warning
- Emergency stop triggered
- High Motor temp
- Battery Control System (BCS) warning
- Traction Control System (TCS) warning
- Air Compressor Warning

**Responsibility:** Depot Control Room

**Control Room to monitor following Alerts :**

- SOC threshold breach
- Temperature spike
- Voltage imbalance
- Charging failure
- Insulation fault
- BMS communication loss
- Battery health degradation

### B. IMMEDIATE SAFETY ACTIONS

**Responsibility:** Driver

**Secure Vehicle on risk identification**
- Park safely, isolate high-voltage system, and Evacuate onboard passengers.
- Report to control room and Depot Manager.

**Responsibility:** Depot Manager

**Dispatch Support**
Send recovery or emergency response if thermal risk is present.

### C. FLEET COORDINATION

**Responsibility:** Depot Manager

- **Deploy Replacement Bus:** Ensure service continuity.
- **Reroute Services:** Adjust schedules and notify passengers.
- **Notify Depot:** Coordinate diagnostics and inspection.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Control Room

**Fleet Operation SOPs for Control Room**
- Maintain communication with driver and emergency responders.
- Share safe parking zones and hazard alerts with other buses.
- Log incident details for post-event analysis.

**Responsibility:** Driver

**SOPs for Driver**

**During battery failure**
- Stop bus immediately and inform passengers about the situation and next steps
- Ensure all passengers exit calmly and move to a safe zone.
- Attempt fire suppression only if safe.
- Report location and hazard status to Control Room.
- Follow towing or evacuation instructions.

**If battery risk escalates**
- Evacuate passengers immediately if smoke or heat is detected
- Use onboard fire suppression system if safe.
- Call emergency services for fire or hazardous conditions
- Do not restart or move the vehicle until cleared
- Avoid contact with high-voltage components

# BATTERY FAILURE

## DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- Smoke or unusual odor from battery
- Abnormal voltage/current on BMS
- Audible alarms from charger or battery
- Sudden shutdown or overheating of battery

**Responsibility:** Depot Manager | Electrical Safety Lead | Charging Operators | Maintenance Team | Safety Officer

### A. BATTERY MONITORING

**Monitor via BMS & SCADA:**

**Responsibility:** Depot Control Room | Maintenance In-charge

**Trigger Alerts to Watch For:**
- Smoke or odor from battery packs
- Abnormal voltage/current readings
- Audible alarms from chargers or battery systems
- Sudden shutdown or overheating during charging
- SOC drop or voltage imbalance
- BMS communication loss

### B. SAFETY PROTOCOLS

**Responsibility:** Depot Manager | Electrical Safety Lead

**Isolate Faulty Battery System:** Disconnect affected battery packs or EVSE units from power.

**Activate Emergency Response:** Alert fire safety team and evacuate nearby personnel if thermal risk is present.

**Suspend Charging Operations:** Stop all charging in affected zones until inspection is complete.

### C. Maintenance & Escalation

**Responsibility:** Depot Manager | Electrical Safety Lead

**Inspect Battery & EVSE Units:** Perform diagnostics, thermal scans, and insulation resistance tests.

**Notify OEM or Technical Support:** Escalate issue if fault is beyond depot-level resolution.

**Quarantine Faulty Equipment:** Tag and isolate damaged components for further analysis.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Charging Operator | Maintenance In charge

**Emergency Isolation SOP for Faulty Battery/EVSE- During Maintenance:**
- Immediately stop all power to the battery system/ EVSE via SCADA or manual disconnect.
- Isolate the affected EVSE or battery from power supply.
- Apply Lockout/Tagout (LOTO) on breakers and connectors.
- Restrict access to the affected area (maintenance/ charging area) and alert nearby staff.
- If smoke or heat is detected, activate fire suppression and evacuate.
- Notify depot manager and emergency services if escalation occurs.
- Log the incident and submit report for SOP compliance.

**Responsibility:** Electrical Safety Lead | Maintenance In charge

**Emergency Isolation SOP for Bus with Faulty Battery in Depot:**
- Do not power on or connect the bus to a charger.
- Evacuate personnel within immediate vicinity of the affected bus.
- Isolate the bus using cones or barriers.
- Wear appropriate PPE (gloves, face shield, fire-resistant gear).Apply lockout/tagout to battery disconnects and auxiliary systems.
- Inspect for swelling, smoke, leaks, or unusual heat.
- Keep fire suppression tools (Class D extinguisher/ sand/ water etc.) nearby.
- Ventilate area if gases are suspected.
- Notify OEM and fire services if thermal risk is high.
- Move bus to quarantine zone once safe.
- Log incident and conduct safety review.

# CYBER THREAT

## FLEET & DEPOT OPERATIONS PROTOCOL

**Trigger Points**
•Unusual system behavior, unauthorized access, data anomalies, or alerts from cybersecurity tools.

**Responsibility** IT Security / Head | Depot Manager/ Fleet | IT support | OEM Technical Support

### A. DETECTION & IMMEDIATE REPORTING

**Responsibility:** IT support | Fleet Operator | Depot Supervisor

On identification of trigger, immediately report the incident to the Depot Control Room and IT Security Lead.
- Record the time, nature, and source of the anomaly.

Avoid interacting further with the affected system.

### B. ISOLATION & CONTAINMENT

**Responsibility:** IT Security / Head

Disconnect affected systems, disable remote access, freeze changes.
Preserve logs for investigation.
Notify staff to avoid affected systems.

### C. RESPONSE ACTIVATION & MANUAL OPERATIONS

**Responsibility:** IT Head | Depot Manager | Fleet Controller

**Activate Cyber Incident Response Team (CIRT)** - Assign roles for investigation, containment, and recovery.
Switch to manual dispatch and route monitoring.
Monitor charging manually and coordinate with drivers via secure channels.
Maintain service continuity using offline tools.

### D. EXTERNAL NOTIFICATION & RECOVERY

**Responsibility:** IT Head | Legal Officer | OEM Support

Inform OEM, cybersecurity partners, and transport authorities.
Notify **CERT-In** or regulators if data breach is suspected.
Conduct forensic investigation and identify vulnerabilities.
Patch systems and restore operations securely.
Validate system integrity before reconnecting to the network.

**Computer Emergency Response Team – India (CERT-In) - is the national nodal agency for cybersecurity incidents under the Ministry of Electronics and Information Technology (MeitY), Government of India.*

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Manager

**SOPs for Depot Manager/ Fleet Controller during Cyber Threat/ attack**
- Acknowledge cyber incident and inform IT Security Lead.
- Secure depot systems and disconnect affected chargers, terminals, or buses.
- Switch to manual operations for charging and dispatch.
- Coordinate with drivers using radio/phone for route instructions.
- Use printed or verbal route plans for dispatch & Track buses manually and log trip and charging data offline.
- Support IT and OEM teams during investigation and recovery.

**Responsibility:** IT Security

**SOPs for IT Head/ security during Cyber Threat/ attack**
- Validate threat and isolate affected systems.
- Disable remote access and save logs.
- Disconnect compromised buses/systems from network.
- Activate backup servers and manual controls.
- Run diagnostics to find breach source.
- Update Depot Manager and Control Room.
- Activate CIRT and block suspicious IPs/accounts.
- Notify CERT-In and OEM if breach confirmed.
- Lead recovery and patch systems.

**Responsibility:** OEM Technical Support

**SOPs for OEM Technical Support during cyber threat/ attack**
- Diagnose vehicle systems (e.g., BMS, telematics).
- Provide firmware patches or resets.
- Validate systems before reintegration.
- Support forensic analysis if needed.

# TECHNOLOGICAL OBSOLESCENCE

## FLEET & DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- OEM announces end-of-life for hardware/software.
- Discontinued support or security patches.
- Spare parts unavailable or incompatible.

**Responsibility:** Depot Manager | Control Room | Fleet Controller | IT Security/ Head

### A. DETECTION & REPORTING

**Responsibility:** Depot Staff | IT Support Personnel

- Identify obsolete systems or unsupported components.
- Report to Depot Manager, Fleet Controller, IT Security Lead.
- Do not attempt manual software updates or unauthorized fixes.

### B. ASSESS & ISOLATE

**Responsibility:** Depot Manager | IT Support Personnel

- Check affected buses, chargers, and IT systems.
- Disconnect unsupported hardware/software from network.
- Disable remote features without security patches.

### C. MAINTAIN OPERATIONS

**Responsibility:** Depot Manager | Fleet Controller

- Switch to manual charging and dispatch.
- Use printed route plans and offline logs.
- Communicate with drivers via secure channels.

### D. COORDINATE & UPGRADE

**Responsibility:** CONTROL ROOM | OEM Technical Support

- Contact OEM for migration roadmap, firmware updates, retrofit kits.
- Negotiate service continuity agreements.

### E. EMERGENCY ACTIONS- SOPS

**Responsibility:** Depot Manager

**SOPs for Depot Manager during technology failure incident**
- Maintain inventory audit of obsolete parts and systems.
- Isolate unsupported chargers or hardware from active network.
- Implement manual scheduling, route management, charging and dispatch if smart systems fail.
- Document all operational changes for compliance.

**Responsibility:** Fleet Controller

**SOPs Fleet Controller technology failure incident**
- Identify buses with outdated BMS or telematics.
- Disable remote features if security patches are unavailable.
- Switch to manual route planning and driver communication.
- Log trips offline until systems are upgraded..

**Responsibility:** IT Security/ Head

**SOPs for IT Head/ security during Technological Obsolescence**
- Validate software versions and patch status.
- Disconnect unsupported systems from network to prevent cyber risk.
- Activate backup servers for fleet data.
- Notify CERT-In if vulnerabilities arise due to obsolescence..

**Responsibility:** OEM Technical Support

**SOPs for OEM Technical Support during cyber threat/ attack**
- Request migration roadmap for hardware/software upgrades.
- Secure firmware updates or retrofit kits.
- Negotiate service continuity agreements for critical systems.

## *Detailed Emergency Protocols and SOPs – Human Induced Hazard*

# PROTEST / VANDALISM

## FLEET & DEPOT OPERATIONS PROTOCOL

**Trigger Points**
- Driver activates panic alert; ADAS Alert
- CCTV detects crowd aggression.
- Depot perimeter breach or unauthorized entry
- Social media or police alert of nearby unrest

**Responsibility:** Depot Manager | Control Room & Communication Team | Maintenance Team | SCADA Operator | Driver

### A. THREAT DETECTION & ALERT ACTIVATION

**Responsibility:** Depot Manager | Control Room

- Monitor CCTV, GPS, and social media
- Receive panic alert from driver or depot staff
- Confirm threat and activate Emergency Operations Center (EOC)

### B. FLEET, PASSENGER AND DEPOT SAFETY

**Responsibility:** Depot Manager | Driver

**Fleet Safety**
- **Instruct driver for enroute fleet safety -** Pull over to a safe location & Lock doors and keep passenger's calm.
- Dispatch emergency support or law enforcement.
- Track affected bus and disable remote charging commands.

**Depot safety**
- Lock depot gates and secure control rooms, suspend charging operations.
- Evacuate non-essential staff
- Apply LOTO to high-voltage systems

### C. INFRASTRUCTURE ISOLATION & MONITORING

**Responsibility:** Maintenance Team | SCADA Operator

- Remotely disable ignition of targeted buses
- Isolate power to chargers and battery banks
- Ensure data logging and system backup
- Monitor infrastructure for tampering or damage

### D. COMMUNICATION & COORDINATION

**Responsibility:** Communication Team

- Send internal alerts to all stakeholders
- Issue public advisories via app/SMS/social media
- Coordinate with PR for media handling
- Share incident details with law enforcement

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Driver

**SOPs for Driver**
- Pull over to a safe location (preferably public, well-lit).
- Lock doors, keep passengers calm, avoid confrontation.
- Do NOT allow anyone near high-voltage connectors or battery compartment.
- Use panic button or radio to alert FCC.
- Avoid verbal or physical interaction with protestors.

**Responsibility:** Depot Manager | SCADA Operator

**Depot Manager SOPs for emergency actions for on-route fleet**
- Track affected bus via GPS
- Communicate with driver and reroute nearby vehicles
- Notify law enforcement and activate EOC
- In case of escalated fire risk, SCADA Operator to remotely disable ignition of targeted buses.
- Monitor vehicle diagnostics and location.

**Responsibility:** Depot Manager

**SOP for Depot Lockdown**
- Action: Initiate Depot Lockdown Protocol.
- Secure: Lock gates, suspend charging operations, Isolate power to chargers and battery banks, restrict access to control rooms and battery storage.
- Evacuate: Move staff to designated safe zones.
- Power Down: Isolate high-voltage systems using LOTO.

# ACCIDENT / COLLISION

## FLEET & DEPOT OPERATIONS PROTOCOL

**Trigger Points**

- Collision | Smoke/sparks from battery compartment after impact | Dashboard alerts for battery fault/ HV system damage.

**Responsibility:** Depot Manager | Technical Team | Operator | Driver

### A. IMMEDIATE REPORTING & PASSENGER SAFETY

**Responsibility:** Driver

Trigger: Collision, passenger injury, smoke, sparks, or fluid leakage.
- Stop bus safely, activate hazard lights.

Call nearest Police Station and Fire Station if needed, inform Control Room.

Evacuate Passengers to a safe distance; ensure no one touches high-voltage components.

### B. ELECTRICAL ISOLATION & HAZARD CONTROL

**Responsibility:** Driver

Action: Use emergency cut-off switch to isolate high-voltage system.
Apply: Lockout/Tagout if possible.
Fire Control: Use extinguisher only if safe; restrict access to battery compartment.

### C. COMMUNICATION & ESCALATION

**Responsibility:** Control Room

Action: Control Room logs incident details (location, severity, passenger status).
Notify: Depot Manager, Operator & Safety Officer.

### D. RECOVERY & TECHNICAL RESPONSE

**Responsibility:** Depot Manager/ Operator | Technical Response

- Attend to the event and report to police station with driver.
- Dispatch recovery vehicle and technical team.

Inspect: Ensure electrical isolation before towing.
Quarantine: Damaged components for investigation.

### D. EMERGENCY ACTIONS- SOPS

**Responsibility:** Driver

**SOPs for Driver post accident/ collision**
- Stop bus, activate hazard lights.
- Isolate high-voltage system using emergency cut-off.
- Evacuate passengers safely.
- Provide first aid while waiting for medical or fire responders.
- Prevent passengers from retrieving belongings or reboarding bus during incident
- Call Police, Fire Station, and Ambulance if accident involves injury or fire risk.
- Do not touch damaged electrical components.

**Responsibility:** Depot / Technical | Operator

**SOPs for Depot team during road accident**
- Assist in rerouting and passenger transfers.
- Do not move the bus if fire, fluids, or structural damage are present; isolate it.
- Apply Lockout/Tagout before handling bus & Tow bus to depot safely.
- Do not restart or move bus until cleared by emergency and technical inspection.
- Inspect battery & high-voltage systems.
- Document damage & initiate repair or replacement.

**Responsibility:** Depot / Technical | Operator

**SOPs for Depot team during bus accident/ collision in depot**
- Stop all charging and bus movement near the incident.
- Report immediately to Control Room and Safety Officer; call Fire/Police if needed.
- Evacuate personnel and restrict access to high-voltage areas.
- Isolate electrical systems using emergency cut-off; apply Lockout/Tagout.
- Use fire extinguisher or activate suppression system only if safe.
- Log incident and notify Depot Manager, Fleet Ops, and OEM.
- Call technical team for inspection and safe removal; quarantine damaged parts.

# LACK OF KNOWLEDGE / MANAGEMENT FAILURE

## E-BUS ECOSYSTEM

## KEY INCIDENTS & STANDARD OPERATING PROCEDURES

Responsibility: Maintenance Team | Depot Manager | Electrician/ Technician | Depot Supervisor

### 1. IMPROPER HIGH-VOLTAGE SYSTEM HANDLING

- **Risk**: Electric shock, arc flash, or fire.
- **Cause**: Inadequate training in Lockout/Tagout (LOTO) procedures or misunderstanding of high-voltage components.
- **Example**: Maintenance personnel working on battery packs without isolating power sources.

**Responsibility:** Maintenance Team

**SOP for High Voltage Handling**

- Perform Lockout/Tagout (LOTO) before any maintenance.
- Verify zero voltage using insulated multimeter.
- Use arc-rated PPE (gloves, face shield, boots).
- Maintain High-Voltage Permit System for authorized personnel only

**Lockout/Tagout (LOTO) for High-Voltage Systems**

- Identify all energy sources (battery, inverter, charger).
- Shut down systems using OEM-recommended sequence.
- Apply lock and tag with technician ID and timestamp.
- Verify zero voltage using insulated multimeter.
- Document and log in maintenance system.

### 2. INADEQUATE BATTERY THERMAL MANAGEMENT

- **Risk**: Thermal runaway, fire, or explosion.
- **Cause**: Poor understanding of battery chemistry and cooling requirements.
- **Example**: Management fails to implement proper monitoring systems or ignores temperature thresholds.

**Responsibility:** Maintenance Team | Depot Supervisor

**Battery Thermal Management**

- Monitor battery temperature via BMS continuously.
- Set alarms for abnormal temperature rise.
- Conduct weekly thermal imaging inspections.
- Store damaged batteries in fireproof containers.
- Depot Supervisor: Schedule inspections and monitor alerts.
- Maintenance Team: Perform thermal checks and report anomalies.

**Frequency: Continuous monitoring + weekly inspection.**

### 3. CHARGING INFRASTRUCTURE MISMANAGEMENT

- **Risk** : Power surges, electrical faults, or grid instability.
- **Cause**: Lack of coordination between fleet operations and utility providers.
- **Example**: Simultaneous fast charging of multiple buses without load balancing or scheduling.

**Responsibility:** Depot Manager | Charging Supervisors

**Handling Charging Infrastructure**

- Implement smart charging software for load balancing.
- Define charging schedules to avoid peak demand.
- Inspect connectors and cables daily.
- Emergency disconnect switches at every charging point.
- Charging Supervisors: Ensure configuration of load balancing and schedules.
- Depot Manager: Perform daily visual checks.

**Frequency: Daily checks + real-time monitoring.**

# LACK OF KNOWLEDGE / MANAGEMENT FAILURE

## E-BUS ECOSYSTEM

**KEY INCIDENTS & STANDARD OPERATING PROCEDURES**

**Responsibility:** Depot Manager | Safety officer | Driver Instructor | IT Security Lead | Maintenance Team

### 4. EMERGENCY RESPONSE FAILURES

- **Risk:** Delayed evacuation, injury, or escalation of incidents.
- **Cause**: Absence of SOPs or staff unaware of emergency protocols.
- **Example**: Fire in depot with no clear evacuation plan or fire suppression system for lithium-ion batteries.

**Responsibility:** Depot Manager | Safety officer

**SOP for Emergency Response**

- Maintain Depot Evacuation Plan with muster points.
- Conduct quarterly fire drills.
- Install automatic fire suppression systems for Li-ion batteries.
- Keep emergency kits and contact list accessible.
- Safety Officer: Conduct drills and update SOPs.
- Depot Manager: Ensure equipment readiness.
- **Frequency:** Quarterly drills + monthly equipment check.
- **Documentation:** Drill reports and equipment inspection logs.

### 5. SOFTWARE AND CYBERSECURITY OVERSIGHTS

- **Risk** : Unauthorized access, data breaches, or remote control of vehicles.
- **Cause**: Poor IT governance or lack of cybersecurity awareness.
- **Example**: Fleet management software not updated, exposing vulnerabilities.

**Responsibility:** IT Security Lead

**SOP for Cybersecurity**

- Enforce multi-factor authentication for fleet software.
- Apply regular patches and updates.
- Conduct quarterly penetration tests.
- Isolate critical systems from public networks
- IT Security Lead: Patch systems and monitor threats.
- Fleet Operations Head: Ensure compliance.
- **Frequency:** Continuous monitoring + quarterly tests.
- **Documentation :** Patch logs and security audit reports.

### 6. INADEQUATE DRIVER TRAINING

- **Risk** : Accidents, improper regenerative braking or energy management.
- **Cause**: Drivers not trained in e-Bus-specific driving techniques.
- **Example**: Misuse of regenerative braking leading to loss of control on wet roads

**Responsibility:** Driver Instructor

**SOPs for Driver Training**

- Mandatory eBus-specific training on regenerative braking and energy management.
- Simulated driving sessions for emergency scenarios.
- Refresher courses every 2 months, counselling every month and toolbox talks (safety briefings) every day
- Training Coordinator: Schedule and track sessions.
- Drivers: Complete certification.
- **Frequency:** Initial + semi-annual refreshers.
- **Documentation :** Training attendance and certification records

### 7. POOR MAINTENANCE SCHEDULING

- **Risk** : Unexpected breakdowns or component failures.
- **Cause**: Lack of predictive maintenance or failure to interpret diagnostic data.
- **Example**: Ignoring battery degradation alerts due to lack of technical understanding.

**Responsibility:** Technicians | Maintenance Team

**SOPs for Maintenance Schedule**

- Implement predictive maintenance using telematics data.
- Weekly diagnostic checks for battery health.
- Maintain digital logs for all inspections and alerts.
- Maintenance Planner: Schedule tasks and monitor alerts.
- Technicians : Execute and log inspections.
- **Frequency:** Weekly + real-time alerts.
- **Documentation :** Maintenance logs and predictive analytics reports.

## Common Emergency Protocols & SOPS

# TRAINING AND SIMULATION SOPS

**E-BUS ECOSYSTEM** | **CRITICAL EMERGENCY TRAINING**

Responsibility: Training Coordinator | CTSO

**Responsibility:** Training Coordinator | CTSO

✅ **Objective:** Ensure all staff can respond effectively to disasters (fire, flood, HV shock, battery failure, cyber attack).

**A. TRAINING SCHEDULE**

- Induction: Within 7 days of joining
- Quarterly Refresher: Mandatory (Critical trainings) for all staff
- Annual Drill: Full-scale multi-hazard simulation

**C. EVALUATION**

- Measure response time
- Check SOP compliance
- Maintain training logs & feedback

**D. CONTINUOUS IMPROVEMENT**

- Update SOPs after incidents or tech changes
- Conduct feedback sessions
- Align with NFPA, OSHA, IEC standards

**B TRAINING MODULES - CRITICAL EMERGENCY TRAINING**

**Passenger Safety**
- Evacuation drills for fire/flood/accident
- Communication practice for calm handling
- Basic First Aid & CPR
- Fire Training
- New driver training programme

**Electrical Safety**
- Lockout/Tagout (LOTO) steps
- Emergency isolation of chargers & HV circuits
- Arc-rated PPE usage

**Battery Safety**
- Detect thermal runaway (smoke, odor, alerts)
- Class D extinguisher handling
- Damaged battery containment

**Control Room Protocols**
- Fleet-wide alert drills
- Emergency coordination with rescue teams
- Remote isolation of compromised systems

**Depot Safety**
- Staff evacuation drills
- Emergency power shutdown practice
- Access control for hazard zones

**Practical Drills**
- Passenger & staff evacuation
- Fire response using extinguishers
- LOTO simulation for chargers & HV systems
- Battery incident containment

# EMERGENCY ENERGY MANAGEMENT SOPS

**EBUS ECOSYSTEM**

**EMERGENCY ENERGY MANAGEMENT SOPS**

**Responsibility:** On-Duty Technician | Depot Manager | Electrical Safety Lead | Safety Officer

## 1. Emergency Power Shutdown

**Objective:** Rapidly de-energize the entire depot power system in case of a critical emergency.

**Triggers**:
- Fire, electric shock, equipment fault, alarms
- Major fire or explosion risk across multiple systems.
- Flooding or water ingress in electrical areas.
- Structural collapse or earthquake.
- Cybersecurity breach or control system failure.
- Emergency services request full power shutdown.

**Responsibility:** Depot Manager | Safety Officer | Electrical Safety Lead

**Procedure**:
- Assess the situation and confirm need for full shutdown.
- Activate Emergency Power Off (EPO) switch or master breaker.
- Confirm shutdown of all systems: chargers, BESS, power distribution, auxiliary loads.
- Notify emergency services and internal safety teams.
- Secure the site and restrict access.
- After resolution, inspect all systems before re-energizing.
- Document the event and update emergency protocols.

## 2. Emergency Isolation for (Charging Infrastructure, BESS rack, HV Bus)

**Objective**: Immediately isolate power to a specific component (e.g., charger, BESS rack, HV bus) during a localized emergency.

**Triggers**:
- Fire, electric shock, equipment fault, alarms
- Visible smoke, fire, or sparks from equipment.
- Electric shock incident or near-miss.
- Abnormal sounds, smells, or overheating.
- Fault alarms from chargers, BESS, or HV systems.

**Responsibility:** Depot Manager | Safety Officer | On-Duty Technician

**Procedure**:
- Identify the affected equipment.
- Activate local emergency stop or isolation switch.
- If safe, isolate upstream power (breaker/disconnect).
- Evacuate personnel from the immediate area.
- Notify control room and emergency response team.
- Secure the area and prevent re-energization.
- Conduct post-incident inspection and root cause analysis.

# PLANNED ENERGY MANAGEMENT SOPS

## DEPOT OPERATIONS

**SAFE ENERGY MANAGEMENT SOPS FOR PLANNED ACTIVITIES**

**Responsibility:** Maintenance Team | Depot Manager | Electrician/ Technician | Safety Officer

### 1. PLANNED LOCKOUT/TAGOUT (LOTO)– ELECTRICAL SYSTEMS

**Objective**: Safely isolate electrical energy during scheduled maintenance or servicing of depot systems (e.g., chargers, switchgear, BESS, onboard HV).
**Triggers**: : Maintenance, inspection, upgrades

**Responsibility:** Maintenance Team | Safety Officer

**SOP for planned lockout/tagout (LOTO) – electrical systems**

- Review electrical schematics and identify all energy sources.
- Notify control room and affected personnel.
- Shut down equipment using standard controls.
- Isolate energy at source (breakers, disconnects, service plugs).
- Apply lockout devices and tag with technician details.
- Verify zero energy using calibrated testers (Category III/ IV multimeters).
- Apply grounding if required.
- Perform maintenance using PPE and insulated tools.
- After work, remove tools, restore system, and remove LOTO devices.
- Document the procedure and close the permit.

### 2. SAFE BATTERY HANDLING & DAMAGED BATTERY MANAGEMENT

**Objective**: Ensure safe handling of EV and BESS batteries during maintenance and manage damaged batteries to prevent hazards.
**Responsible**: Battery Technician, Safety Officer
**Triggers**:

- Scheduled maintenance or replacement.
- Inspect for damage (swelling, leakage, odor) and avoid passenger overload.
- Post-incident checks (collision, fire, thermal event). Safe end-of-life disposal.

**Responsibility:** Maintenance Team | Technician | Safety Officer

**SOP for Safe Handling Practices**:

- Only trained personnel to handle batteries.
- Wear PPE: arc-rated clothing, insulated gloves, safety goggles.
- Remove metal jewelry; use insulated tools.
- Follow LOTO before any battery work.
- Avoid dropping, crushing, or puncturing cells.
- Ensure proper ventilation; avoid water near battery terminals.
- Monitor for heat, swelling, or unusual odors.

**SOP for Handling Damaged Batteries**

- Do not move or open damaged batteries without assessment.
- Isolate area and notify safety team immediately.
- Use insulated tools and chemical-resistant gloves.
- Place damaged batteries in fire-resistant containers.
- Store in a cool, ventilated, secure area with hazard signage.
- Arrange for certified disposal or recycling with support from E-bus OEM.
- Document incident and update battery handling logs.

# STAFF AND PASSENGER SAFETY SOPS FOR FIRST RESPONDERS

**EBUS ECOSYSTEM**

**EMERGENCY SOPS FOR FIRST RESPONDERS**

**Responsibility:** Maintenance Team | Depot Manager | Electrician/ Technician | Depot Supervisor

## 1. POLICE

**Triggers**: Accident/ collision, Crowd gathering near bus or depot, fire, smoke, escalated risk

**Responsibility:** Police

**SOP for Polices for on road accident or escalated fire risk**

- Establish perimeter to keep public away from bus and HV components.
- Prevent unauthorized access to depot or accident site.
- Help move passengers and staff to safe muster points.
- Manage traffic and prevent panic situations.
- Liaise with depot manager and emergency services for updates.

## 2. Fire Department

**Triggers**: Visible smoke, flames, or thermal runaway alert. BMS alarm for overheating or fire risk.

**Responsibility:** Fire Department

**SOP for Fire Department for fire/ smoke/ thermal incidents**

- Approach from upwind, maintain safe distance initially.
- Confirm emergency cut-off is engaged before firefighting.
- Use **Class D or clean agent extinguishers or water** for suppressing battery fires as suggested by OEMs.
- Ensure all passengers and staff are evacuated before suppression.
- Declare area safe for recovery after thermal risk is eliminated.

## 3. Traffic Police

**Triggers**: Road accident involving eBus. Fire or thermal event blocking traffic.

**Responsibility:** Traffic Police

**SOP for Traffic Police on road accident or escalated fire risk :**

- Block lanes around incident site to prevent secondary accidents.
- Reroute traffic away from incident location.
- Create emergency corridor for fire trucks and ambulances.
- Guide passengers to safe zones away from traffic.

## 4. Hospitals / Medical Teams

**Triggers**: Injuries reported from accident or fire. Smoke inhalation or burns detected.

**Responsibility:** Hospitals/ Medical Teams

**SOP for Hospitals / Medical Teams :**

- Immediate Medical Aid to treat smoke inhalation, burns, or injuries onsite.
- Arrange ambulances for critical cases.
- Keep burn units and emergency wards ready for mass casualty scenarios.

# SAFE EVACUATION OF STAFF/ PASSENGER SOPS

**EBUS ECOSYSTEM**

**EMERGENCY SOPS FOR FIRST RESPONDERS**

**Responsibility:** Driver | Technicians | Depot Manager | First Responders | Safety Officer

## 1. SAFE EVACUATION OF PASSENEGRS ON ROAD

**Responsibility:** Driver

**Step 1- Driver Actions**

- Stop bus safely, activate hazard lights.
- Switch off ignition and engage HV emergency cut-off.
- Announce evacuation calmly; instruct passengers to leave belongings.
- Guide passengers to move to a safe distance away from affected bus, preferably upwind.
- Call emergency services and control center.

**Step 2: Passenger Safety**

- Assist elderly, disabled, injured and vulnerable passengers first.
- Keep passengers together at a safe muster point.
- Prevent anyone from approaching battery or HV components.

**Responsibility:** Traffic Police | First Responders/ Technicians | Fire Department

**Step 3: Support Team**

- Traffic Police: Divert traffic, create emergency corridor for first responders.
- First Responders/ Technicians: Isolate HV system, assist evacuation.
- Fire Department: Suppress fire using **Class D or clean agent extinguishers or water** as suggested by OEMs

## 2. SAFE EVACUATION OF STAFF at DEPOT

**Responsibility:** Depot Manager | Safety Officer

**Step 1: Alarm Activation**

- Automatic fire alarm or thermal alert (both visual and acoustic) triggers evacuation.
- Depot staff initiates Depot Evacuation Plan as practiced during the mock drills.

**Step 2: Staff Actions**

- Move all personnel to designated safe points/ zones.
- Account for staff using attendance logs/ manual counting.
- Lockdown depot to prevent unauthorized entry.

**Responsibility:** Technicians | Safety Officer

**Step 3: Hazard Control**

- Technicians: Isolate HV systems, move buses away from fire zone.
- Safety Officer: Coordinate with fire department and emergency services

# DAMAGE & SAFETY CHECK SOP (FIRE INCIDENT)

**EBUS ECOSYSTEM**

**EMERGENCY SOPS FOR FIRST RESPONDERS**

**Responsibility:** Depot Manager | Technical Team | Maintenance Team | Safety Officer

## 1. DAMAGE & SAFETY CHECK SOP (FIRE INCIDENT)

**Responsibility:** Safety Officer

**Step 1: Ensure Scene Safety**
- Confirm fire is fully extinguished and area declared safe by Fire Department.
- Wear arc-rated PPE, insulated gloves, and face shield before approaching.

**Responsibility:** Technical Team

**Step 2: High-Voltage Isolation**
- Verify HV system is disconnected using emergency cut -off.
- Check voltage with insulated multimeter (category III or IV) before touching any components.

**Responsibility:** Technical Team

**Step 3: Battery Inspection**
- Look for signs of damage: swelling, leakage, burn marks, odor.
- Use thermal imaging to confirm no residual heat or hotspots.
- Quarantine damaged battery in a fireproof container.

**Responsibility:** Maintenance Team

**Step 4: Structural & Electrical Check**
- Inspect wiring harness, connectors, and insulation for burns or melting.
- Check inverter, charger, and control units for heat damage.

**Responsibility:** Safety Officer

**Step 5: Safety System Verification**
- Confirm fire suppression system activation and refill if discharged.
- Inspect emergency exits and signage for damage

**Responsibility:** Depot Manager | Safety Officer

**Step 6: Documentation**
- Record all findings in incident report.
- Capture photos of damaged components.
- Log actions in maintenance system for root cause analysis.

# 8. POST DISASTER STRATEGIES

The framework outlines standardized post disaster response protocols across four major components: E-Bus, Charging Infrastructure, Depot, and Enroute Operations. Each component follows a structured sequence of recovery and rehabilitation actions after any hazard event (floods, heatwaves, vandalism, technological hazard etc.).

## 8.1. Post Disaster Activities

The key activities to be undertaken post any hazards are:

*Table 42 Post Disaster Activities and its Responsibility Mapping*

| S.N. | Activities | Responsibility |
|---|---|---|
| **1** | **Immediate Isolation for safety & Securing Site** | |
| | • Evacuate from and isolate in all affected areas (e.g., damaged buses, depot zones, charger enclosures).<br>• Cut off power supply to chargers and non-essential depot systems to prevent cascading failures.<br>• Establish physical cordons and signage to restrict unauthorized access.<br>• Use lockout/tagout protocols for high-voltage systems (especially relevant for EVs). | • On route – Crew, Emergency response team<br>• At Depots: Depot Manager, Safety Supervisor |
| **2** | **Rapid Impact & Safety Assessment** | |
| | • Conduct a visual inspection of fleet, depot buildings, chargers, and road infrastructure.<br>• Record initial damage and safety risks/signs (e.g., battery smoke, collapsed walls, exposed wiring).<br>• Deploy OEM-certified technicians for e-bus and charger systems.<br>• Report critical observations to central command (e.g. Transport Department, Disaster Authority, DISCOM, Fire Safety). | • Fleet Operator<br>• Depot Manager<br>• Safety Officer<br>• Certified Technician |
| **3** | **Technical Inspection & Diagnostics** | |
| | • Perform system-level diagnostics:<br>○ Fleet: Batteries, Battery Management System (BMS), traction motors, steering and braking system, communication system and the driver console / dashboard, Lights and signalling devices, door opening/ closing systems, low voltage battery system.<br>○ Chargers: Insulation resistance, power flow, thermal performance, water ingress.<br>○ Depot: Electrical panels, water ingress, structural safety.<br>○ ITS: Data integrity, server uptime, system functionality, communication operability.<br>• Use OEM tools to evaluate key systems (BMS, grid connections, server functionality). | • Fleet: OEM / Bus Manufacturer/ Workshop Engineers – Electrical & Mechanical<br>• Chargers: OEM/ Charging Infra Vendor/ Electrical Engineer<br>• Grid Infra: DISCOM<br>• Depot: Structural engineer, Depot Manager<br>• ITS: ITS Vendor / System Integrator |
| | • Categorize **assets** as: ☐ **Safe to operate** ☐ **Safe with minor repair** ☐ **Unsafe – needing replacement or further assessment** | • Certified Technician / OEMs/ Workshop Staff |

| S.N. | Activities | Responsibility |
|---|---|---|
| 4 | **Interim Restoration of Services** | |
| | • Deploy standby fleet or reroute services using unaffected assets.<br>• Operate temporary/ emergency charging points if primary ones are non-functional.<br>• Implement manual dispatching and operations if digital systems are compromised.<br>• Maintain deployment of buses to keep critical facilities like hospitals, transit hubs prioritized during limited operations. | • PT- Planning & Operations Team |
| 5 | **Repair, Recommission & Testing** | |
| | • Clean, repair, and test affected systems before reintroducing into service.<br>• Repair, replace or isolate damaged components.<br>• Ensure inspections by safety and electrical officials as needed. | • Maintenance Team,<br>• OEMs<br>• Bus Manufactures<br>• ITS/ system integrator vendor |
| 6 | **Verification, Documentation & Third-Party Clearance** | |
| | • Seek fit to **operate certification** from:<br>○ **Structural engineers** (for depots)<br>○ **OEMs** (Certified EV technicians) (for fleet and chargers)<br>○ **Fire or electrical safety** officials (for major hazard incidents) | • Structural engineers<br>• OEMs, EV technicians<br>• Fire or electrical safety officials |
| | • Prepare formal documentation of:<br>○ Incident reports; Technical inspection checklists; Photos, diagnostics, and recommissioning logs<br>○ File an incident report with: Date, time, location; Bus ID and operator; Sequence of events; Passenger/operator safety outcomes and Initial observations.<br>○ Submit report to relevant authority as required - Transport Authority / Nodal Agency; Insurer; OEM or supplier; Safety auditor (if mandated) | • Safety Officer<br>• Operator |
| 7 | **Asset Insurance** | |
| | • Assess vehicles for repair feasibility and battery reusability<br>• Process insurance claims for damage, downtime, or third-party loss.<br>• Decommission asset if required. | • Bus Operator, Finance & Legal Department |
| 8 | **SOP Revision, Institutional Strengthening & Capacity Building** | |
| | • Following Incidence investigation reports, Revise and update:<br>○ **Standard Operating Procedures (SOPs)**<br>○ **Emergency Response Plans (ERPs)**<br>○ **Asset risk registers**<br>• Conduct post-event debriefings and simulation drills.<br>• Train depot staff, crew, and emergency teams based on learnings. | • Training Cell,<br>• Operator,<br>• Depot manager<br>• Lead Disaster Response Officer<br>• Technicians/ Electricians |
| 9 | **Long-Term Resilience Upgrades** | |
| | • Identify systemic gaps from post-disaster assessments.<br>• Plan for: | • Administration- Bus Transport Agency |

| S.N. | Activities | Responsibility |
|---|---|---|
| | ○ Infrastructure elevation (for flood-prone depots)<br>○ Flood Resilience Planning (such as optimum area drainage plan, rainwater harvesting, plantation, porous pavements, multi-level parking)<br>○ Retaining Structures (For Landslide prone depots)<br>○ Fire-rated charging enclosures<br>○ Enhanced backup power and communications<br>• Align upgrades with climate and disaster resilience frameworks (e.g., ADB CDRI, NDMA guidelines). | |

### 8.1.1. Post Hazard Interim Restoration of Services Action Plan

The following action plan outlines the procedures and responsibilities for ensuring the rapid restoration and continuity of essential e-bus services in the aftermath of a disaster.

## CONTINGENCY PLANS FOR MAINTAINING ESSENTIAL SERVICES POST DISASTER

**EBUS OPERATIONS**

**POST DISASTER ESSENTIAL SERVICE OPERATIONS**

Responsibility: Depot Manager | Planning & Operations Manager

### A. PRE DISASTER PREPAREDNESS

**Responsibility:** Planning & Operations manager

**Pre – Disaster Assessment**

- Identify essential routes connecting key facilities (hospitals, police, shelters, stations, administrative centres, schools CBDs).
- Prioritize routes:
  - Priority 1: Essential Services (must operate)
  - Priority 2: Desirable Services (operate as conditions allow)
  - Priority 3: Non-essential Services (Resume post stabilization)
- Develop alternate routes for Priority 1 corridors to bypass high-risk or obstructed areas.
- Map routes with available charging points to ensure service continuity during disruptions.

**Responsibility:** Depot Manager

**Pre – Preparedness Protocol**

- Define roles, command structure & reporting hierarchy for contingency activation.
- Develop a structured Contingency Plan with route maps, priorities & contact list.
- Integrate the plan into city disaster and mobility frameworks.
- Conduct biannual mock drills to test service continuity.
- Maintain an inventory of critical spares & tools for rapid restoration.
- Review & update the plan annually or post major disasters.

### B. EMERGENCY ACTIONS - SOPS

**Responsibility:** Depot Manager

**Essential Service Post Disaster Action Plan**

- Identify safe depots and charging points as emergency operation base.
- Ensure emergency power backup at critical depots & charging stations (DG sets, battery units, or mobile chargers).
- Deploy alternate fuel buses (ICE/CNG) if e-buses are non-operational until normal operations are restored.
- Create emergency bus lanes or bridges for priority movement.
- Activate Priority 1 routes with trained drivers post-safety clearance.
- Mobilize resources including tow vehicles, mobile chargers, fuel supply.
- Establish clear communication protocols with power utilities, traffic police, and disaster management authorities for coordinated response.
- Offer fare-free services on essential routes during post recovery.
- Monitor operations and safety throughout reduced operations.

### 8.1.2. Post Hazard Assessment Checklist for Components

The following checklist be used for quick damage assessment of EBES during post hazard impact.

### A. E-bus checklist

*Table 43 Post Hazard checklist for E-Bus Component*

| Aspect | Checklist Items |
|---|---|
| **Vehicle Inspection** | ☐ Check battery pack and modules for damage, overheating or water ingress, cables for damages, connections for tightness / corrosion etc.<br>☐ Visually inspect body and undercarriage for cracks, leaks, or mechanical faults.<br>☐ Inspect low voltage batteries for intactness of positive locking of terminal ends, cables for cracks / electrolyte spillage, etc; head lights, wiper system, brake and indicator lights for functioning, proper fastening/functioning of transmission and steering systems and their joints, oil leakages, hub bolts, entry / exit doors operation, brake system operation |
| **Electrical Safety** | ☐ Disable BMS (Battery Management System) before diagnostics.<br>☐ Test insulation resistance and grounding of high-voltage systems. |
| **Telematics & Sensors** | ☐ Verify the functionality of GPS, camera, Acoustic Vehicle Alerting System (AVAS), dashboard systems, Passenger information display boards, GPRS/ cellular communication system and on-board fare collection systems.<br>☐ Check ECU (Electronic Control Unit) and backup data integrity. |
| **Test Operations** | ☐ Conduct no-load dry run before re-commissioning.<br>☐ Monitor energy draw patterns and regenerative braking function. |

### B. Depot Facilities

*Table 44 Post Hazard checklist for Depot Infrastructure and Management component*

| Area | Checklist Items |
|---|---|
| **Structural Safety** | ☐ Conduct structural audit of roofs, columns, walls, and entry gates.<br>☐ Inspect ramps, drainage, bus lanes for cracks or blockages, bus inspection pits for water logging / leakages, bus circulation plan within the depot. |
| **Water & Fire Systems** | ☐ Test sump pumps, stormwater drains, and waterlogging systems.<br>☐ Check fire alarms, extinguishers, sprinklers. |
| **Electrical Rooms** | ☐ Ensure battery rooms, server rooms, and UPS enclosures are dry and safe. ☐ Assess energy meters and grid backup systems.<br>☐Assess safety and functioning of standby generator and low voltage battery chargers. |
| **Staff & Operations** | ☐ Set up temporary workspaces or shelters if depot is damaged. ☐ Account for staff availability and wellbeing. |

### C. Charging infrastructure

*Table 45 Post Hazard checklist for Charging Infrastructure component*

| Area | Checklist Items |
|---|---|
| **Physical Damage** | ☐ Inspect chargers, connectors, cables for breakage, warping, water entry.<br>☐ Secure charger enclosures and check for tilting or instability. |
| **Power Systems** | ☐ Test transformers, switchgear, and circuit breakers for overload signs. |

| | |
|---|---|
| | ☐ Ensure grounding and lightning protection system are intact. |
| **Software & Controls** | ☐ Reset and test communication systems (OCPP/comms protocols).<br>☐ Run firmware diagnostics and software updates. |
| **Safety Systems** | ☐ Check for proper ventilation, heat dissipation, and fire suppression units. |

## D. Operating environment

*Table 46 Post Hazard checklist for Operating Environment component*

| Area | Checklist Items |
|---|---|
| **Route Accessibility** | ☐ Survey routes for obstructions, sinkholes, waterlogging, landslide, tree falls or for any other obstruction.<br>☐ Reroute buses away from damaged bridges or flyovers. |
| **Bus Stops & Terminals** | ☐ Inspect passenger shelters, signage, lighting, and surveillance.<br>☐ Confirm tactile paths and railings are intact for safety.<br>☐ Check for the PIS, Security cameras, electrical equipment and fare collection system if any, are safe and operational. |
| **ITS Systems** | ☐ Test VMS (Variable Message Signs), adaptive signals, CCTV.<br>☐ Coordinate with traffic police to manage detours and control points. |
| **Power & Communication Lines** | ☐ Inspect for damaged poles, snapped cables, or loose conductors.<br>☐ Request immediate repair from utility agencies. |

Sample form for post hazard **damaged assessment form** placed at Annexure E and a **detailed hazard specific checklist** placed in Annexure F, shall be used by officials for through assessment.

### *8.1.3. Additional Detailed Checklist for Post Hazard Assessment*

The post-disaster management framework includes standardized tools and checklists to support rapid assessment, recovery, and restoration of e-bus operations. **Annexure E provides a Post-Disaster Damage and Safety Assessment Form** to be completed within hours of an incident for quick evaluation of fleet, depot, and charging infrastructure conditions. **Annexure F presents hazard-specific checklists** covering various disaster scenarios including floods, heatwaves, earthquakes, battery failures, grid outages, cyber threats, vandalism, accidents, and human negligence to guide systematic inspection, documentation, and corrective action across all operational components.

# PART C :

# Enablers of E-Bus Ecosystem: People, Policies and Preparedness

This section highlights the human, organisational, and financial support required to create a disaster-ready EBES. It focuses on building adaptive capacity through specialised and targeted training, well-defined institutional roles, and robust coordination across agencies. Financial resilience is bolstered through insurance, contingency funds, and rapid recovery mechanisms. Coupled with supportive policies and regulations, these measures transform preparedness into actionable capability ensuring that, when disruptions strike, the system, its people, and its finances respond swiftly and effectively.

# 9. Institutional Backbone of the Disaster Response System

The EBES needs improvement in strengthening the **centralised coordination mechanism** for resilience, with scope to enhance **clarity of roles** and **streamline responsibilities** across departments. **Public bus transport agencies** would benefit from enhanced **capacity building**, particularly through targeted training for managing fire risks, battery failures, and cyber threats. Additionally, there is potential to formalise and strengthen **Inter-agency collaboration**, enabling more coordinated and effective response mechanisms.

Planning process should integrate **risk-informed approach**, including hazard mapping and predictive tools. **Emergency protocols** should be well-defined and effectively implemented to enable **proactive and structured responses**. With increasing digitalisation, robust cybersecurity governance is essential to safeguard systems. Accordingly, this section proposes a streamlined institutional architecture to support a disaster-resilient EBES.

## Proposed Institutional Structure

A single designated Safety Official, called **Chief Transport Safety Officer (CTSO)** is advised to be appointed in the State Transport Undertaking (STU) / Municipal Corporation / Special Purpose Vehicle (SPV) / Public Bus Agency to streamline safety management and support the achievement of clear accountability. This official can serve in the capacity of the nodal authority for all aspects related to disaster resilience, incident response, and safety of the EBES covering fleet operations, depot infrastructure, and charging systems.

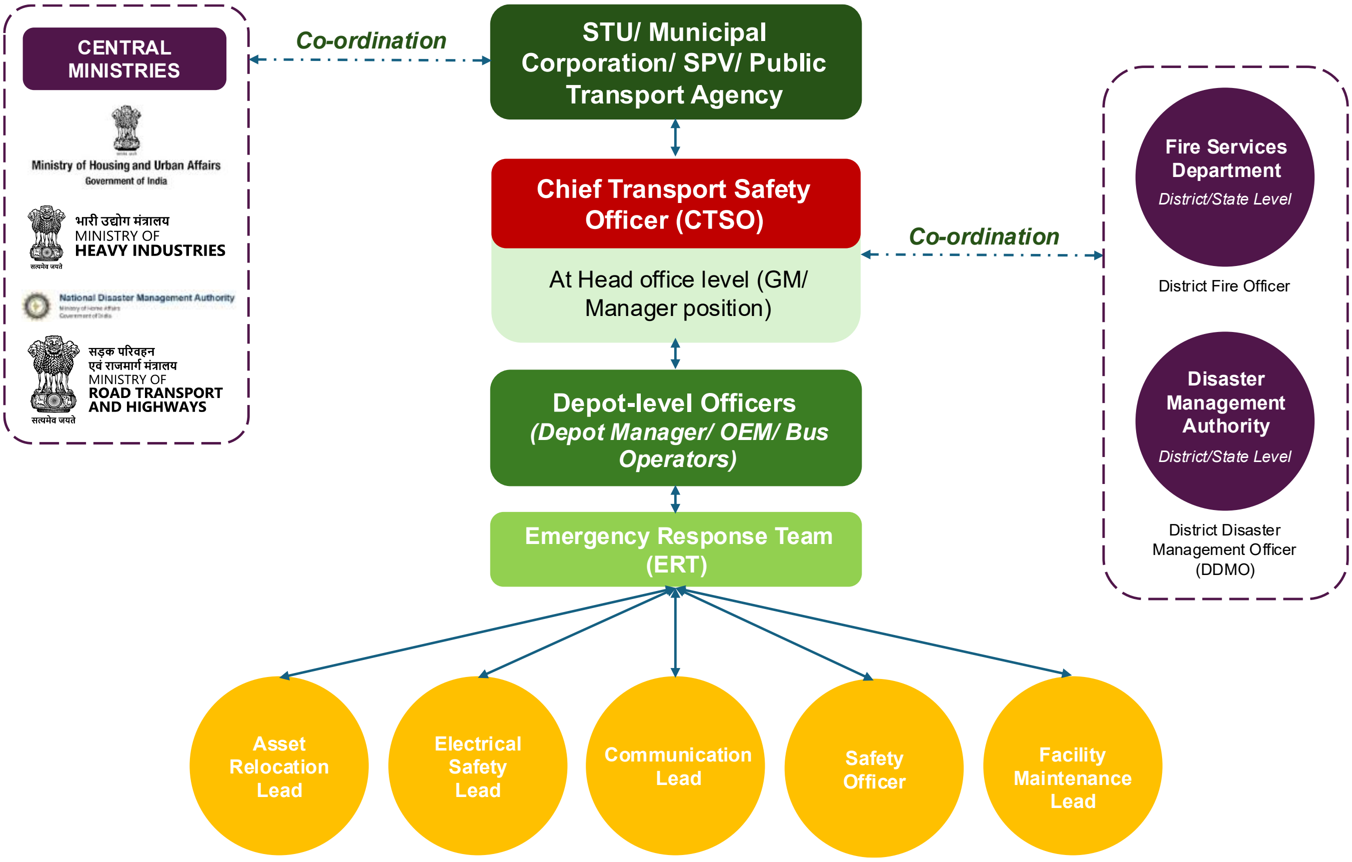


*Exhibit 73: Proposed Institutional Structure*

The role is intended to streamline safety management through a centralized structure. Its implementation does not necessarily require entirely new hiring. Agencies may leverage existing personnel and roles, aligning them with the proposed institutional framework and assigned additional responsibilities where feasible. However, for critical functions requiring dedicated oversight, creation of new positions may be considered.

### Key Roles & Responsibilities of Chief Transport Safety Officer (CTSO)

1. **Disaster Preparedness & Risk Mitigation**
   - Develop and maintain safety and disaster management protocols for e-bus operations.
   - Encourage integration of climate resilience measures in depot design and operations.
2. **Coordination & Communication**
   - Serve as the liaison between transport agencies and stakeholders such as the Fire Department, Disaster Management Authority (DMA), OEMs, and operators.
   - Facilitate timely information exchange and decision-making during emergencies.
3. **Emergency Response Oversight**
   - Support the activation of emergency protocols during incidents such as fires, floods, or cyberattacks.
   - Coordinate on-ground response teams to assist with passenger safety and asset protection.
4. **Training & Capacity Building**
   - Organise periodic training and mock drills for staff involved in disaster response.
   - Recommend safety induction for new staff prior to deployment.
5. **Preventive Maintenance & Safety Audits**
   - Promote regular safety inspections of buses, depots, and charging infrastructure.
   - Encourage alignment with OEM safety recommendations and standards.
   - Facilitate quarterly audits and annual third-party evaluations to assess safety compliance.
6. **Regulatory & Policy Compliance**
   - Support adherence to applicable safety regulations and environmental norms.
   - Update policies based on evolving risks and technologies.
7. **Post-Incident Review & Improvement**
   - Conduct reviews of incidents to identify root causes and suggest preventive measures.
   - Revise protocols based on lessons learned.

### Safety Support Structure under the Chief Transport Safety Officer (CTSO)

To ensure efficient execution, the CTSO can be supported by three specialized safety coordinators

1. **Fleet Safety Coordinator**
   - Supports monitoring of on-road operations and encourages driver alignment with safety protocols.
   - Collaborates with the control room during emergency situations.
   - Maintains records related to fleet inspection and operational readiness.

2. **Depot Safety Coordinator**
   - Contributes to making depot infrastructure disaster-resilient and aligned with safety standards.
   - Facilitates oversight of storage, maintenance, and repair activities with a safety-oriented approach.
   - Assists in developing and updating evacuation plans and emergency exit strategies.
3. **Charging Infrastructure Safety Coordinator**
   - Supports monitoring of charging operations and promotes electrical safety practices.
   - Coordinates with power utilities and OEMs to enable safe recovery in case of hazards.
   - Encourages adherence to battery handling, cooling, and fire prevention measures.

## Formation of Emergency Response Team (ERT)

To support the achievement of swift, coordinated, and effective response during emergencies affecting the EBES including incidents related to high-voltage systems, EV charging infrastructure, battery storage, and facility operation, it is imperative to establish a dedicated Emergency Response Team (ERT) in STUs under Depot-level officers (Depot Manager/ OEM/ Bus Operator). This team is advised to be constituted through nomination by the senior management and facility heads and can operate under the overarching disaster management framework of the organization.

### *Composition of the ERT*

The ERT consists of the following designated roles, each with clearly defined responsibilities:

1. **Asset Relocation Lead**
   - Supports identification and prioritization of movable assets (e.g., buses, equipment, data records).
   - Facilitates safe relocation of electric buses, charging units, and auxiliary equipment.
   - Helps maintain asset relocation maps and contingency plans.
2. **Electrical Safety Lead**
   - Assists in isolating high-voltage systems and encourages adherence to Lockout/Tagout (LOTO) procedures.
   - Coordinates with utility providers and internal electrical teams.
   - Participates in periodic electrical hazard assessments and emergency drills.
3. **Communication Lead**
   - Supports internal and external communication during emergency situations.
   - Encourages timely dissemination of alerts, instructions, and status updates.
   - Engages with local authorities, emergency services, and media as needed.
4. **Safety Officer**
   - Contributes to monitoring safety practices during emergency operations.
   - Promotes the use of personal protective equipment (PPE) and alignment with safety protocols.
   - Maintains incident logs and assists with post-event reviews.
5. **Facility Maintenance Lead**

- Aids in maintaining the operational integrity of critical infrastructure (e.g., ventilation, fire suppression, lighting).
- Coordinates emergency repairs and utility restoration efforts.
- Helps keep facility layout and emergency access plans updated.

**Coordination Mechanism**

The Chief Transport Safety Officer (CTSO) may follow suggested coordination mechanism:

- Report to the Head of the Public Bus Agency (STU/Municipal Corporation/SPV)
- Participate in regular coordination meetings with Fire Department, and Disaster Management Authorities.
- Support the activation of emergency response protocols during disasters and promote smooth inter-agency communication.
- Emergency Response Team may coordinate with depot-level officers.

## National Level Roles and Responsibility

### 1. Updation of Rules/ Acts/ Policy/ Standards

To strengthen institutional preparedness and regulatory compliance for e-bus safety and resilience, relevant rules, acts, and standards is advised to be updated to address emerging risks associated with electric mobility. This includes integrating EV-specific safety, fire, and disaster management provisions into existing frameworks and ensuring coordination among responsible agencies. Detailed recommendations for policy amendments, institutional roles, and regulatory updates are provided in Chapter 12 Policy and Regulatory Recommendations.

### 2. Incident Monitoring and Reporting

The Urban Transport department under the Ministry of Housing and Urban Affairs (MoHUA) is encouraged to take the lead in maintaining a centralised repository for safety-related incidents and hazards in the electric mobility sector, both nationally and globally. Other line ministries may provide the necessary input to support the achievement of periodic updating of the same.

- **Centralised Safety Log:** It is suggested to maintain a centralised log capturing safety-related incidents, near misses, and hazards both within the depot and from global experiences along with context and corrective actions taken.
- **Post-Incident Assessment:** Teams may consider reviewing post-incident outcomes to identify any changes in industry practices, technological upgrades, or handling procedures that could enhance future preparedness.
- **Relevance Mapping:** It is recommended to assess the relevance of each incident and its corrective actions to the organization's operations, helping identify applicable lessons and improvement opportunities.
- **Continuous Updating:** Safety registers may be updated regularly with new incidents, response measures, and learnings to foster ongoing improvement and institutional learning.

### 3. Establishment of National Level Empanelment Framework for Third Party Safety Audit

Given the limited technical and financial capacity of public bus transport agencies, the need for an independent and unbiased safety oversight mechanism is critical. In this context, the Urban Transport Department under the Ministry of Housing and Urban Affairs (MoHUA) may take the lead in establishing a national-level empanelment of certified third-party safety audit agencies.

This empanelment should be based on clearly defined Terms of Reference (ToR), technical expertise, and regional coverage to ensure quality and consistency in assessments. The empanelled agencies would be responsible for conducting periodic inspections and safety audits, and for submitting formal recommendations to support improved safety, compliance, and resilience across the e-bus ecosystem.

# 10. Capacity Development - Preparing Teams for E-Bus Disaster Response

A well-structured training and capacity-building ecosystem is considered essential for enhancing the safety, reliability, and resilience of the electric bus ecosystem across the country. As e-mobility systems evolve with increased digitalisation, high-voltage components, and interconnected infrastructure there is a growing need to equip stakeholders with relevant technical skills, risk awareness, and operational protocols. This chapter outlines a suggested approach to identifying stakeholder-specific training needs across various risk domains and emphasizes the value of inter-agency collaboration in designing and delivering effective training programs.

## 10.1. Mapping of training needs for various stakeholder

Each stakeholder group, from planners to field operators, may benefit from role-specific training that builds technical, safety, and emergency response capabilities. The following section presents a suggested mapping of training modules; however it is not exhaustive. Training content may be further customized and expanded based on the specific needs of the target audience.

Training can be delivered through existing Learning Management Systems (LMS) platforms, leveraging current institutional infrastructure. A blended approach is recommended, combining online and offline modes, including classroom sessions and simulation-based training, depending on the nature and complexity of the modules. This flexible approach will help enhance skill development, ensure better retention, and improve preparedness across stakeholders.

*Table 47 Mapping of various training modules for various stakeholder*

| **Module 1: Driver Safety & Emergency Response** | |
|---|---|
| *Target Audience* | *E-Bus Drivers, Field Supervisors, Technicians* |
| **Sub-Modules** | • Appreciation of EBES, its components, basic operating principles and likely hazards of each sub-system, role in handling the hazards, communication system and safety of assets, on-board persons and other road users and the SOPs in each case.<br>• Detection of Hazard signal and communication protocol<br>• Emergency Evacuation Procedures – Step-by-step response during fires, flooding, and other emergencies<br>• Fire Suppression Basics – Use of fire extinguishers and suppression systems onboard<br>• Waterlogging Protocols – Driving techniques and safety precautions in flooded streets<br>• Electrical Fault Indicators – Recognizing fault signals and alarms<br>• Post-Accident Handling – What to do after a collision or physical damage |
| *Expected Outcome* | *Drivers and field staff are expected to develop a foundational understanding of the EBES, recognize early warning signs, perform safe shutdowns, evacuate passengers during emergencies, and maintain control in hazardous conditions while following communication protocols.* |
| **Module 2: Depot Incident Response and Risk Management** | |
| *Target Audience* | *Depot Managers, Depot Engineers, First responder, Depot Staff.* |

| | |
|---|---|
| **Sub-Modules** | • Appreciation of Depot Organisational structure, sections and sub-sections, responsibility matrix of each section; basics of operating principles of EBES, its sub-systems, key challenges and hazards associated with each sub-system; hazard warning indicators and signals, handling these hazards; coordination requirement with different agencies, safety and security of assets and the staff, communication and coordination protocols, post hazard rehabilitation and investigation mechanisms, learnings therefrom and updating of SOPs.<br>• SOPs for Fire, Cyber, and Physical Threats – Role-based response playbooks<br>• Emergency Shutdown Protocol – Isolating systems in event of incident<br>• Coordination Mechanisms – Engaging with fire dept., DISCOMs, and IT teams<br>• Safety Audits – Conducting internal depot safety evaluations<br>• Cyber Hygiene Basics – Recognizing and reporting cyber threats<br>• Rehabilitation of the system, investigation post incident, identification of causes, learnings form investigation, up-dation of SOPs |
| *Expected Outcome* | *Depot teams are expected to support structured incident response, collaborate with emergency agencies, promote SOP alignment, and contribute to routine safety and cyber hygiene practices.* |
| **Module 3: Technical & Maintenance Safety** | |
| *Target Audience* | *Depot Manager, Depot Engineer, Operations Manager, Electrical Supervisor, Maintenance Teams* |
| Sub-Modules | • Basics of EBES, its sub-system, their operating mechanism, Battery chemistry and operating characteristics, likely hazards associated with each sub-system, hazard warning signals, prevention of hazards, handling and mitigation of the hazards, rehabilitation after the hazard, hazard investigation and learning from hazard, up-dation of SOPs<br>• Battery Inspection & Safe Handling at different stages – Preventing thermal runaway and leakages<br>• Electrical Safety – Earthing, insulation, circuit protection standards<br>• Sealing Protocols – Waterproofing measures for monsoon preparedness<br>• Handling Physically Damaged Hardware – Dealing with bent frames, exposed wires.<br>• Storage and Handling of new, repairable and repaired batteries, collision/ roll-over affected e-buses.<br>• Storage, disposal and repurposing, and transporting of batteries at End-of Life. |
| *Expected Outcome* | *Staff are expected to be skilled in safely inspecting, repairing, and handling high-voltage battery systems, performing regular electrical safety checks (earthing, protection circuits), sealing vulnerabilities* |

| | |
|---|---|
| | *against water ingress, and addressing physical damage to vehicles without causing secondary risks.* |
| **Module 4: Charging Infrastructure Operations** | |
| *Target Audience* | *Depot Manager, Depot Engineer, Electrical Supervisor, Maintenance Staff, Charging Infrastructure Operators* |
| **Sub-Modules** | • Appreciation of charging systems, their operating principles and the process; merits, demerits, and preferred usage of each of the charging systems; preventive maintenance procedures and precautionary measures; possible safety and other hazards, identification and mitigation measures, post hazard investigation, rehabilitation process; learnings from investigation and up-dation of SOPs<br>• Installation and commissioning of the chargers – preparation, procedures and precautions<br>• Charging Safety – SOPs for plug-in/plug-out and power checks<br>• Suppression Systems – Installation and use of fire safety equipment<br>• Emergency Shutdown – Manual and remote protocols for power off<br>• Software Cybersecurity – Handling login credentials, malware risk awareness |
| *Expected Outcome* | *The concerned staff and charging operators are expected be equipped to operate charging stations in line with technical and safety standards, implement secure software protocols to prevent cyber breaches, initiate fire suppression systems in case of charging-related fires, and conduct emergency disconnection and power cut-off actions swiftly.* |
| **Module 5: Grid Coordination and Emergency Response** | |
| *Target Audience* | *Depot Manager and Depot Engineer, Electrical Engineer/Supervisor, Charging operators, DISCOM Engineers* |
| **Sub-Modules** | • Assessment of connected load, characteristics of connected power at charger head-voltage, current, frequency; distribution side components, their characteristics and relationship with the charging station; operating environment for chargers-heat, water, flooding safety; high voltage cables and their safe layout planning; connectors and connecting protocols to e-buses; possible hazards related to chargers and the charging process, hazard indicators, identification and mitigation measures; post hazard investigation, learnings and up-dation of SOPs.<br>• Load Management – Planning for EV-related load balancing<br>• Emergency Isolation – Power cut-off in case of depot or grid incidents<br>• Incident Collaboration – Working with depots and emergency responders |
| *Expected Outcome* | *Staff are expected to be adept at monitoring and managing EV grid load dynamics, implementing preventive grid safety protocols, initiating power disconnection during emergency incidents, and working collaboratively with depot, DISCOM and fire services during fire or electrical emergencies.* |

| Module 6: ITMS and Control Room Emergency Monitoring | |
|---|---|
| *Target Audience* | *Depot Manager and Depot Engineer, ITMS Staff, Operations Team and First Responders* |
| **Sub-Modules** | • Appreciation of ITS and its sub-systems, their generalised application and operating mechanism; outputs expected and their utility; threats and hazards- their understanding, identification and preventive measures; post-hazard mitigation, and learnings; up-dation of SOPs.<br>• Cybersecurity Protocols – Secure passwords, phishing identification<br>• Incident Alert Systems – Use of automated alert and ticketing tools<br>• Digital Logging – Real-time event reporting and data traceability<br>• Remote Monitoring SOPs – Responding to abnormal data feeds or shutdowns |
| *Expected Outcome* | *Staff are expected to be trained to detect, log, and escalate cyber intrusions or operational incidents using digital tools, respond rapidly to alerts from onboard and depot systems, ensure secure data handling, and communicate effectively with field teams during emergencies.* |
| **Module 7: Fire Management and Coordination** | |
| *Target Audience* | *Depot Manager, Depot Engineer, Depot Safety Officer and Staff; Operator, Technicians, Fire Department* |
| **Sub-Modules** | • Appreciation of EBES- its components and sub-systems; identification of fire prone areas – symptoms and signals; propagation of fires in e-buses; Thermal run away mechanism and identification; fire suppression and control methods; precaution during handling fire incidents; need for isolation of e-buses involved in collisions / roll-overs and other hazards likely to cause fire; isolation space requirement and space location in depot; investigation of causes of fire, rehabilitation of the system; learnings and up-dation of SOPs<br>• EV Fire Suppression – Lithium-ion battery-specific firefighting<br>• Battery Awareness – Understanding thermal runaway, battery structure<br>• High Voltage Safety – Use of insulated tools, rubber gloves, etc.<br>• Depot Interface – Coordination with depot teams during fire |
| *Expected Outcome* | *Staff are expected to be equipped to handle EV-related fires with an understanding of battery and charger-specific hazards, apply specialized suppression techniques, use protective equipment suitable for high-voltage systems, and execute coordinated rescue and fire control in collaboration with depot and DISCOM teams.* |
| **Module 8: Policy Oversight & Coordination** | |

| | |
|---|---|
| *Target Audience* | *City/State Transport Officials/STU, Fire department, Disaster Management authority* |
| **Sub-Modules** | • Compliance Training – Understanding relevant EV safety norms<br>• Audit Protocols – Evaluation frameworks for depots and bus operators<br>• Inter-Agency SOPs – Response alignment between transport, fire, and power |
| *Expected Outcome* | *Officials are expected to gain competencies in auditing depot and fleet safety, evaluating inter-agency preparedness, enforcing regulatory compliance, and ensuring that city and state-level e-bus operations are resilient, safe, and integrated with broader emergency response mechanisms.* |

## 10.2. Training Evaluation and Emergency Readiness

To support operational readiness, a structured evaluation framework may be considered:

- **Knowledge & Skills Assessment:** Pre- and post-training tests and hands-on practice
- **Emergency Response Time:** Tracking reaction time during drills
- **Mock Drills:** Simulated scenarios to build confidence
- **On-the-Job Monitoring:** Supervisors observe real-world application of training
- **Feedback Loop:** Continuous updates based on trainee and trainer feedback

## 10.3. Interagency Collaboration

To build a robust and disaster-resilient EBES in India, focused capacity building and training efforts is advised to leverage the strengths and mandates of multiple agencies. In addition to existing entities that supports e-bus safety trainings such as OEMs, service provider, vendor (BMS, CMS, ITS etc), the other key institutes be leveraged for training and capacity building. The following are key recommendations for intra-agency collaborative training programs aligned with national priorities and value-driven outcomes:

### 1. Disaster Management Authorities – National, State, District (NDMA, SDMA, DDMA)

**Current Role:** These agencies are responsible for disaster policy, planning, and capacity building at various administrative levels.

**Potential Areas for Collaboration:**

- National level: Exploring ways to integrate EV systems into broader disaster frameworks and developing e-mobility-specific preparedness modules.
- State/District level: Including electric mobility in disaster response plans, conducting joint drills with transit agencies, and identifying risks related to climate-induced disruptions.

### 2. Fire Departments (State and Municipal)

**Current Role:** Responding to fire emergencies and conducting rescue operations. **Potential Areas for Collaboration:**

- Familiarization with e-bus systems and their components.
- Understanding fire risks specific to EVs and appropriate mitigation strategies.
- Training on battery fire suppression, high-voltage safety, and coordinated emergency response at depots and charging stations.

### 3. Urban Local Bodies (ULBs)

**Current Role:** Managing city-level infrastructure and services, including urban transport.
**Potential Areas for Collaboration:**

- Planning and development of e-bus infrastructure.
- Risk mapping related to urban transport and e-bus systems.
- Emergency planning at depots and coordination with responders for fleet evacuation and public communication.

### 4. National Institute of Disaster Management (NIDM)

**Current Role**: Leading training, research, and capacity building for disaster risk reduction.
**Potential Areas for Collaboration**:

- Developing national-level Training of Trainers (ToT) programs.
- Creating curricula for state-level agencies.
- Conducting vulnerability assessments related to e-mobility.

### 5. District Disaster Response Force (DDRF)

**Current Role:** Coordinating on-ground emergency responses.
**Potential Areas for Collaboration:**

- Training on immediate response protocols for EV-related incidents such as fires, floods, or crashes.
- Enhancing coordination between first responders and transit agencies.

### 6. Civil Society Organizations (CSOs) and NGOs (e.g., SEEDS, RedR India)

**Current Role:** Engaging communities and building local capacity.
**Potential Areas for Collaboration:**

- Raising awareness about safe e-bus usage during emergencies.
- Organizing evacuation drills and ensuring inclusion of vulnerable groups in preparedness efforts.

### 7. National and International Development Agencies (e.g., GIZ, World Bank, UITP, WRI)

**Current Role:** Providing technical assistance, funding, and knowledge sharing.
**Potential Areas for Collaboration:**

- Sharing global best practices in EV disaster risk reduction.
- Co-developing resilience toolkits and planning **tools.**

A collaborative training framework involving these stakeholders could help align efforts with national goals, build institutional capacity, and foster a culture of preparedness across the EBES. Agencies such as MoHUA, NDMA, and NIDM may consider facilitating these efforts, with support from SDMAs for state-level implementation.

Additional institutions may also be explored for partnership:

- Research Institutions (e.g., TERI, CSTEP, AEEE, DRRF): Can contribute through risk analytics, climate modelling, and evidence-based policy support.
- Training Institutes (e.g., IRTE, ASCI, CIRT, CISF*): May offer specialised training in areas such as cybersecurity, infrastructure security, and emergency response.

**CISF – National Industrial Security Academy (NISA) may support training related to industrial security and protection of technological assets.*

# 11. Financing Resilience - Smart Financing for Hazard-Proof E-Bus Systems

E-buses are high-value assets with specific vulnerabilities, particularly during events such as floods, earthquakes, or grid instability. Given these risks, it is advisable to integrate financial and risk resilience considerations into planning and operations. Compared to conventional buses, e-buses include components like battery packs, electric drivetrains, and charging infrastructure, which may be more sensitive to environmental conditions. Strengthening the financial resilience of e-bus projects can contribute to long-term viability and continuity of service.[62]

## 11.1. Existing Challenges in E-Bus Financing During Disasters

Despite the growth in e-bus deployments across Indian cities, several persistent challenges in financing resilience against various disasters remain:

- **High Repair and Replacement Costs**: Battery and electronic control systems are expensive and often require full replacement post-disaster.
- **Inadequate Insurance Coverage**: Many insurance packages do not comprehensively cover battery fires or water ingress, especially under catastrophic natural conditions.
- **Revenue Disruptions and delay recovery funding**: Prolonged service disruptions not only reduce fare revenue but also delay operational cost recovery, creating cash flow crises.
- **Creditworthiness Impact**: Lenders may perceive disaster-hit operators as higher risk, tightening financing terms or increasing interest rates.
- **Limited Private Sector Appetite**: Due to unclear risk-sharing mechanisms and absence of robust guaranteed frameworks, lenders and operators remain cautious.
- **Delayed Government Reimbursements**: Post-disaster compensations are often general-purpose and not tailored for EV-specific equipment.

## 11.2. Role of Risk Insurance Mechanisms

To address these challenges, tailored insurance solutions are emerging as important tools for financial resilience. It is suggested that e-bus risk insurance be considered during procurement and contracting processes.

### a. EV Fire Insurance

- May cover thermal events such as battery failures or short circuits.
- Add-on modules could be offered for high-value EV assets.

### b. Water Ingress Insurance

- Designed to address damage from flooding or water seepage into sensitive components[63].
- Particularly relevant for cities like Mumbai, Chennai, and Kolkata, which experience heavy seasonal rainfall.

[62] NITI Aayog & Rocky Mountain Institute (2021). Mobilising Finance for EVs in India
[63] IRDAI-Approved Product Documentation, "Flood and Ingress Damage Add-on for EVs" (2023).

### c. Composite Risk Insurance Packages

- These products may combine coverage for EV-specific risks and natural disasters. (e.g., battery, electronics) and natural calamities (floods, earthquakes, fires).

## 11.3. Role of National and State Government Budget Support

While insurance is a critical pillar, premium costs and limited availability necessitate additional support from government budgets.

### a. Dedicated Contingency Funds for EV Resilience

- Cities may consider allocating contingency funds under Smart Cities Mission or Urban Mobility Plans to support emergency repairs and fleet restoration.
- Central schemes (e.g., FAME-II, PM-E-Drive) could be adapted to include resilience provisions.

### b. Viability Gap Funding (VGF) Adjustments

- State and central VGF allocations (used in GCC and PPP contracts) may include a “risk buffer” to help offset disaster-related financial impacts.

### c. State-Level Green Resilience Bonds

- States may explore earmarking portions of green bonds for EV system resilience (e.g. Tamil Nadu and Maharashtra have proposed green bonds for infrastructure; a portion can be earmarked for EV system resilience.)

### d. Integration with Climate Adaptation Programs

- Urban resilience strategies could be aligned with EV infrastructure planning and disaster risk reduction.

### e. Parametric and Indemnity-Based Risk Insurance Models

- Parametric Insurance: May offer quicker payouts based on predefined triggers. Example: Nagaland’s 3-year parametric DRI model which is of Higher cost but easier claims process for government agencies[64]
- Indemnity-Based Insurance for GCC Operators: Could be more cost-effective for private operators and integrated into GCC bids. CESL may consider recommending this approach

## 11.4. Recommendations and Way Forward

- **Risk-Based Insurance**: It is recommended to include insurance provisions in all e-bus procurement and operational contracts.
- **Depot Resilience Audits**: Structural and climate vulnerability assessments may be conducted for depots and charging infrastructure.
- **EV Risk Pooling**: A national-level disaster guarantee or insurance fund could be considered.

[64] Mongabay; First payout under extreme-weather insurance triggers relief and intrigue; 2025

- **Self-Insurance Models**: public bus transport agencies may explore maintaining reserve pools or insurance cesses to support recovery efforts.
- **Inclusion of Omnibus Clause in Insurance Framework:** It is recommended to incorporate an "omnibus clause" in e-bus insurance policies to extend coverage to all authorised personnel operating the vehicle, including employed and contracted drivers[65]. This will ensure comprehensive coverage of accidents, reduce the need for multiple policies, and limit legal and financial exposure of the insured entity. Its inclusion will support more structured management of risks related to accidents, asset damage, and third-party liabilities, thereby strengthening financial resilience.
- **Inter-Agency Coordination**: EV operations may be aligned with SDMAs and District Emergency Response Teams.
- **Policy Integration**: Risk financing and resilience measures could be embedded within state EV policies and action plans.

Scaling up e-buses presents an opportunity to integrate financial planning with disaster preparedness. A combination of insurance products, fiscal instruments, and policy alignment can help cities transition to clean transport in a way that is resilient, financially secure, and future ready.


[65] Automobile Insurance – Omnibus Clause

# 12. Policy & Regulatory Recommendations

With the increasing adoption of e-buses under national missions such as FAME II, PM E-DRIVE, PM E-Bus Seva, and multiple state-level EV policies, the need for a resilient and safe EBES has become paramount. Recent incidents involving water ingress, thermal runaway, and depot fires highlight critical safety gaps. Despite the increasing deployment of e-buses, significant policy and regulatory gaps persist. Strengthening the safety and resilience of e-bus operations requires a clear understanding of existing regulatory and policy gaps affecting e-bus safety, while outlining practical and actionable pathways to address these gaps. It underscores the need to enhance disaster resilience, operational safety, and regulatory oversight by systematically integrating resilience considerations across legal frameworks, institutional arrangements, technical standards, and contractual mechanisms. The section further emphasizes that the development of a safe and resilient e-bus ecosystem depends on coordinated action and effective oversight by relevant central and state authorities.

The following sections outline the key thematic areas under which gaps have been assessed and corresponding strategic recommendations have been presented.


*Exhibit 74 Key thematic areas under which policy and regulatory gaps have been assessed*

## 12.1. Motor Vehicles Rules and EV Specific Safety Standards

This theme examines the adequacy of existing motor vehicle rules and technical standards in addressing EV-specific safety risks in e-buses, particularly those related to battery systems, environmental exposure, and post-crash scenarios. It highlights gaps in current CMVR provisions and underscores the need for strengthened EV-specific safety standards, testing, and certification to ensure uniform, nationally consistent safety outcomes.

*Table 48 Thematic Area Motor Vehicle Act and Safety Standards*

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| **National:**<br>• **Ministry of Road Transport & Highways (MoRTH)**<br>• **Standard Formulation Agencies (Automotive Industry Standards Committee, Bureau of Indian Standards)** | • The Central Motor Vehicle Act (CMVA) and Central Motor Vehicle Rules (CMVR) currently provide limited guidance on battery insulation and enclosure safety, flood-resilient vehicle design, and post-crash battery monitoring and handling. | • Revisions to CMVR may include:<br>o EV-specific safety provisions related to battery management systems, electric shock prevention, and post-crash fire protection.<br>o Environmental protection standards such as higher Ingress Protection (e.g., IP68 protection level) ratings for batteries and high voltage electrical components in e- |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| • **Testing & Certification Agencies (ARAI, ICAT, CIRT, etc.)** | | buses operating in flood-prone or coastal regions.<br>○ Strengthened vehicle certification processes through accredited testing agencies to ensure OEM compliance with evolving safety technologies and global standards. |

**Relevance and Institutional Benefits:**

- Provides clear, nationally consistent safety benchmarks for battery insulation, ingress protection, and post-crash safety, reducing ambiguity in vehicle approvals.
- Strengthens the ability of the STUs to make informed, safety-led procurement and fleet induction decisions, rather than relying solely on OEM-defined specifications.
- Enhances regulatory oversight through accredited testing and certification processes, ensuring OEM compliance with evolving safety technologies and global standards.
- Improves disaster resilience and operational continuity of e-bus fleets by minimizing safety incidents and service disruptions.
- Reinforces the role of transport authorities as safety regulators while safeguarding public investments in electric mobility infrastructure.

## 12.2. Procurement, Concession Agreements and Compliance

The theme focuses on the role of procurement processes and concession agreements in shaping safety outcomes for e-bus operations, highlighting gaps in the systematic inclusion of EV-specific safety requirements, emergency preparedness, and compliance mechanisms. It identifies opportunities to strengthen tenders and contracts by embedding enforceable safety obligations, audit frameworks, and performance-linked accountability across operators, OEMs, and depot infrastructure.

*Table 49 Thematic Area Procurement, Concession Agreements and Compliance*

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| **National:**<br>**Convergence Energy Services Limited (CESL)** | • Many e-bus tenders and concession agreements needs strengthening on:<br>○ Absence of Standardized safety clauses specific to e-bus operations.<br>○ No mandatory depot safety certification or periodic safety audits.<br>○ Limited flexibility for public bus transport agencies in | • Safety requirements may be systematically embedded in all e-bus tenders and agreements through:<br>○ Mandatory EV Specific safety protocols and training requirements<br>○ Explicit incorporation of third-party inspections and periodic audits as part of concession documents. |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| | specifying safety-related design parameters. | ○ Clearly defined penalties and key performance indicators (KPIs) related to safety and emergency preparedness.<br>○ Mandatory submission of battery health data by bidders for all e-buses supplied, enabling continuous monitoring of battery performance. |
| **State/ Urban:**<br>**Public Bus Transport Agencies (STU/ MTU/ SPV)** | • Many e-bus tenders and compliance agreements currently exhibit the following gaps:<br>○ Lack of Structured SOPs which can be applied for disaster and emergency situations.<br>○ Limited availability of trained and accredited safety inspection personnel<br>○ Inconsistent application of EV-specific Depot Safety Parameters<br>○ Limited disclosure of safety performance and compliance status. | • Safety requirements may be systematically embedded in all e-bus tenders and agreements through:<br>○ Require operators & public bus transport agencies to develop, implement, and periodically update SOPs for EV-related emergencies, aligned with state disaster management frameworks<br>○ Assessment of the existing and establish mechanism for the training, accreditation or empanelment of safety professionals.<br>• Compliance with standardized national-level e-bus depot design guidelines is recommended, including but not limited to:<br>○ Fire separation zones and segregation of charging bays<br>○ Integrated fire detection, alarm and suppression systems<br>○ Adequate access for fire tender and emergency vehicles<br>○ Flood-resilient depot layouts, raised plinths were required, and effective drainage systems.<br>○ Installation of clear and standardized safety signage across depot premises.<br>○ Mandatory safety certification prior to commissioning and periodic re-certification at defined intervals to strengthen compliance and operational oversight. |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| | | • A structured system for periodic audits and monitoring is recommended:<br>○ Recommend three to six monthly safety audits by STA/ third party/ fire department for fit to operate certification.<br>○ Recommend safety audits every 2 years through statutory bodies like fire department, DDMA or other designated authorities<br>○ Maintain public registry of audit scores and compliance history. |

**Relevance and Institutional Benefits:**

- Embeds safety and disaster preparedness as enforceable contractual obligations rather than advisory provisions.
- Strengthens the ability of STUs to regulate operators and OEMs through clear safety-linked performance metrics.
- Reduces operational and financial risks by ensuring early identification of safety gaps in vehicles, depots, and charging infrastructure.
- Improves accountability and transparency through third-party audits and public disclosure of compliance performance.
- Builds long-term institutional capacity through training, accreditation, and standardized safety oversight mechanisms.

## 12.3. Fire Safety Regulations for E-buses

The theme focuses on strengthening fire safety regulations for e-buses by examining the adequacy of existing fire safety frameworks in addressing EV specific risks. It highlights critical regulatory gaps related to lithium-ion batteries, high-voltage systems, and charging infrastructure, and outlines areas where targeted updates to state and national regulations can significantly enhance operational safety and regulatory clarity.

*Table 50 Thematic Area Fire Safety Regulations*

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| **National:**<br>**Ministry of Housing & Urban Affairs (MoHUA)** | • Existing MoHUA guidelines do not sufficiently account for EV-specific fire risks, resulting in fragmented adoption of safety practices and reliance on conventional fire norms that may be inadequate for electric bus operations. | • Ministry of Housing & Urban Affairs (MoHUA) should recommend the integration of EV-specific fire safety requirements into urban bus depot planning norms, urban transport guidelines and centrally supported schemes |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| | • Current MoHUA manuals (e.g., Manual for Planning, Design and Implementation of City Bus Depots) often focus on traditional, retrofitted diesel layouts rather than specialized, purpose-built electric hubs. | such as PM E-Bus Sewa scheme, making compliance with prescribed fire safety standards a condition for financial assistance and project approvals. State Government may also consider linking financial incentives, viability gap funding, or infrastructure support for e-bus depots to compliance with prescribed EV-specific fire safety standards, thereby reinforcing uniform adoption at the city and operator level.<br>• MoHUA should also recommend compliance with these fire safety provisions in their guidelines for all e-bus depots developed or operated by Urban Local Bodies (ULBs) and Special Purpose Vehicles (SPVs). |
| **State:**<br>• **State Fire Services /Directorate of Fire**<br>• **Emergency Services** | • Most State Fire Acts do not explicitly recognize fire risks associated with Lithium-ion battery systems, High-voltage power electronics and Electric bus charging infrastructure.<br>• Fire safety inspections for depots and workshops are generally conducted using norms applicable to conventional fuel-based vehicles, which may be inadequate for addressing EV-specific risks.<br>• At present, many e-bus depots and charging facilities commence operations without a structured, EV-specific fire safety certification process. The absence of standardized "fit to operate" criteria increase operational risk. | • It is recommended that all e-bus depots and associated infrastructure obtain fire safety clearance including a fit to operate or No objection certificate from the State/ City Fire Department prior to start of operations based on the verification of the:<br>  ○ Depot Layout<br>  ○ Separation spacing of Charging Bays<br>  ○ Thermal Monitoring systems<br>  ○ Emergency Access compliance besides any other aspects<br>• State Fire Acts and associated rules may be updated to:<br>  ○ Recognize Class E fire risks linked to high-voltage battery systems and power electronics in e-buses.<br>  ○ Recommend fire suppression systems suitable for lithium-ion and other battery chemistries in buses, depots, and charging areas.<br>  ○ Mandate inclusion of thermal runaway, battery management |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| | | system failure, and short-circuit risks in fire risk assessments. |

**Relevance and Institutional Benefits:**

- Clear and EV-specific fire safety provisions reduce ambiguity in approvals and inspections, improve preparedness of fire services and minimize asset damage, service disruption, and post-incident liability.
- Such certification mechanisms provide STUs with assurance of operational readiness, standardized benchmarks for depot approval and improved accountability of operators and concessionaires.

## 12.4. Incident Reporting and Safety Monitoring

The theme focuses on strengthening incident reporting and safety monitoring mechanisms for e-bus operations by addressing the absence of a centralized, national-level system for capturing and analysing e-mobility related safety incidents. It highlights the need for institutionalized data collection, post-incident learning, and cross-state knowledge sharing to support evidence-based safety improvements in the urban transport sector.

*Table 51 Thematic Area Incident and Monitoring Report*

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| **National:**<br>**Urban Transport Department, MoHUA** | • No centralized system for systematically capturing and analysing safety incidents related to electric mobility hazards. | • A national-level incident reporting and monitoring repository, led by the Urban Transport Department under the Ministry of Housing and Urban Affairs (MoHUA), is recommended to capture information under the following heads:<br>○ Centralised Safety Log: It is suggested to maintain a centralized log capturing safety-related incidents, near misses, and hazards both within the depot and from global experiences along with context and corrective actions taken.<br>○ Post-Incident Assessment: Team may consider reviewing post-incident outcomes to identify any changes in industry practices, technological upgrades, or handling procedures that could enhance future preparedness. |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| | | ○ Relevance Mapping: It is recommended to assess the relevance of each incident and its corrective actions to the organization's operations, helping identify applicable lessons and improvement opportunities.<br>○ Continuous Updating: Safety registers may be updated regularly with new incidents, response measures, and learnings to foster ongoing improvement and institutional learning.<br>• Other line ministries may provide the necessary input to support the achievement of periodic updating of the same. |

**Relevance and Institutional Benefits:**

- Enable consistent reporting of e-bus safety incidents.
- Facilitate cross-state learning and knowledge dissemination.
- Support evidence-based improvements in safety standards and operational practices.

## 12.5. Integration with Disaster Management Frameworks

The theme examines the integration of electric bus related risks within existing disaster management frameworks, highlighting gaps in sector specific preparedness, inter-agency coordination, and emergency response protocols. It identifies opportunities to strengthen disaster management plans by explicitly addressing e-bus operational hazards and clarifying institutional roles across transport, fire, and disaster response agencies.

*Table 52 Thematic Area Disaster Management Frameworks*

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| **State:**<br>• **State Disaster Management Authority (SDMA)**<br>• **Public Bus Transport Agencies (State Transport Department / State Transport Undertaking)** | • Under the Disaster Management Act, State Governments are mandated to prepare and implement State Disaster Management Plans in alignment with the National Plan, and State Disaster Management Authorities (SDMAs) are required to ensure that all line departments, including State Transport Departments, prepare sector-specific disaster management plans. However, | • It is recommended that the Disaster Management Plans for State Transport Departments be updated to explicitly address disaster scenarios related to public transport systems, with specific provisions for e-bus operations, including:<br>○ Identification and assessment of e-bus–specific risks, such as battery fires, thermal runaway, |

| Stakeholder | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| | existing State Transport Department disaster management plans largely lack provisions and standard operating procedures for public bus transport and e-bus–specific risks, limiting the effectiveness of preparedness and emergency response to electric mobility–related hazards. | water ingress in depots, and post-accident thermal incidents.<br>○ Development and inclusion of Standard Operating Procedures (SOPs) for prevention, preparedness, response, and recovery related to e-bus thermal and electrical hazards.<br>○ Clear roles and responsibilities of transport authorities, depot operators, fire services, and emergency responders in managing e-bus–related incidents.<br>• E-bus depot infrastructure could be recognized as critical urban infrastructure within disaster planning frameworks. |
| **Urban:**<br>**Urban Local Bodies (ULBs) / Municipal Corporations/ Special Purpose vehicles/ Municipal Transport Undertakings etc.** | • Every municipal corporation in India has mandate to develop city-level disaster management plan that involves critical infrastructure services, including public transportation. However, there is a recognized gap in comprehensively addressing e-bus related hazards and moving beyond treating public transport solely as a relief resource (i.e., just for evacuation) to integrate it into active, risk-aware, disaster-resilient operational plans that has specific operational SOPs for new technologies like e-buses.<br>• Lack of inter-agency coordination between transport departments, STUs, fire services, SDMA/ DDMA/ UDMA and other relevant agencies during emergencies. | • It is recommended to collaboratively develop an emergency response plan involving all the relevant authorities such as Transport Departments, Fire Services, SDMA/DDMA/UDMA, STUs/SPVs, Municipal Corporations, DISCOMs and OEMs.<br>• Clear delineation of roles, escalation procedures, and communication protocols is essential to reduce response time and operational confusion.<br>• E-bus depot infrastructure could be recognized as critical urban infrastructure within disaster planning frameworks. |

**Relevance and Institutional Benefits:**

- Clear delineation of roles, escalation procedures, and communication protocols is essential to reduce response time and operational confusion.

## 12.6. Policy Alignment and Cross-sectional risk management

This theme focuses on strengthening policy alignment and cross-sectoral risk management for electric bus infrastructure by integrating disaster resilience and safety considerations across transport, electric mobility, and disaster management frameworks. It highlights gaps arising from limited coordination among line ministries and disaster management authorities and identifies opportunities to embed safety and resilience requirements as conditionalities within national and state electric mobility schemes.

*Table 53 Thematic Area Policy Integration and Cross-Sectional Risk Management*

| | Existing Regulatory Context | Recommended Regulatory Strengthening |
|---|---|---|
| **National:**<br>• **Ministry of Road Transport & Highways (MoRTH)**<br>• **Ministry of Heavy Industries (MHI)**<br>• **Ministry of Housing & Urban Affairs (MoHUA)** | • Absence of explicit resilience and safety compliance requirements within various national-level electric mobility and e-bus schemes, resulting in inconsistent consideration of disaster preparedness and operational safety. | • Disaster resilience and safety compliance may be integrated as conditional requirements under:<br>○ FAME II<br>○ PM E-DRIVE<br>○ PM E-BUS SEVA<br>○ National Electric Mobility Mission<br>○ State EV Policies |
| **State/ Urban:**<br>• **State Disaster Management Authorities (SDMAs) / District Disaster Management Authorities (DDMAs),**<br>• **Public Bus Transport Agencies (State Transport Department/ State Transport Undertaking)** | • Limited involvement of disaster management authorities in developing or applying safety rating and risk assessment frameworks for e-bus depots, covering natural, technological, and human-induced hazards.<br>• State-level electric mobility and e-bus schemes often lack clearly defined resilience and safety compliance provisions, leading to uneven incorporation of disaster preparedness and operational safety measures. | • A safety rating system for e-bus depots may be adopted by STUs or Disaster Management Authorities, based on parameters such as:<br>○ Structural fire safety<br>○ Disaster Preparedness<br>○ Environmental Clearance<br>○ Digital Monitoring systems<br>○ Only depots meeting predefined safety thresholds may be issued occupation certificates<br>• Disaster resilience and safety compliance may be integrated as conditional requirements within state electric mobility schemes and EV policies. |

**Relevance and Institutional Benefits:**

- Integrates disaster management authorities into the safety governance of e-bus depots, ensuring systematic assessment and safety rating framework for depots, for various natural, technological, and human-induced hazards.
- Encourages proactive risk reduction by incentivizing depot operators and STUs to invest in disaster preparedness and safety upgrades.
- Aligns safety and resilience outcomes with national and state electric mobility schemes, ensuring public funds are directed toward compliant and risk-prepared infrastructure.
- Supports long-term operational continuity and asset protection by embedding resilience criteria into policy incentives and funding eligibility.

# 13. CONCLUSION

The Guidance Document on Building Resilient E-Bus Ecosystem (EBES) provides a comprehensive framework to strengthen the resilience of India's rapidly expanding e-bus network against natural, technological, and human-induced hazards. It brings together technical, operational, institutional and financial dimensions into a unified strategy that ensures safety, continuity, and sustainability across the entire e-bus value chain.

The guidance aligns national, state and city level policy frameworks with Indian and international standards (CMVR, AIS, BIS, UNECE, IEC) and recommends critical policy reforms such as integrating EV-specific risks in the Motor Vehicles Act and State Fire Acts, introducing depot safety certifications, and developing a national EV hazard map and safety-rating system. It further outlines hazard-specific strategies spanning prevention, mitigation, and restoration for floods, cyclones, heatwaves, grid instability, fires, and cyber threats, supported by robust engineering design, inspection protocols, maintenance routines, and real-time monitoring systems.

By outlining a clear institutional structure anchored by a Chief Transport Safety Officer and supported by dedicated safety coordinators for fleet, depots, and charging infrastructure, the document establishes accountability and enables timely decision-making. It emphasizes capacity building across all stakeholder groups, equipping drivers, depot staff, first responders, OEMs, policymakers, and operators with the knowledge and tools to identify risks, follow emergency protocols, and undertake post-incident recovery.

Financial resilience is reinforced through dedicated EV-risk insurance products, contingency funds, and adaptive financing mechanisms that protect public assets and enable rapid service restoration.

Through this document, cities can assess their current EBES, identify critical gaps, and adopt targeted interventions to enhance resilience. It serves guiding document for policymakers, DISCOMs, state transport undertakings (STUs), private operators, depot managers, and safety officers offering strategic clarity for building a technically sound and disaster-ready e-mobility system. The document is intended to be read and applied along with prevailing policies and guidelines notified by responsible line ministries electric buses or electric mobility ecosystem.

Collectively, these measures ensure that India's transition to a fully electrified is not only sustainable but also resilient, capable of withstanding and recovering swiftly from future shocks while safeguarding public safety, infrastructure, and investment.

# 14. ANNEXURE

## 14.1. Annexure A - Risk Assessment for an e-bus depot in Indian city

**This content does not reflect any specific Indian city. A hypothetical city has been used solely for illustrative purposes in developing the risk assessment framework.*

**Step 1: Hazard analysis:** Hazard analysis is conducted for an Indian city A[66] based on the data available through primary and secondary sources. The table below illustrates detailed analysis.

| ***Hazard Analysis for a City*** | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low**<br>**0** | **Low**<br>**1** | **Moderate**<br>**2** | **High**<br>**3** | **Very High**<br>**4** | **City A** |
| **1. Floods** | | | | | | |
| **24-hour Rainfall over an area** | <15.6 mm | 15.6 – 64.4 mm | 64.5 – 115.5 mm | 115.5 – 204.4 mm | >204.5 mm | 4 |
| **Historical flood frequency for last 10 years** | No reported floods | Rare | 2/3 floods (moderate occurrence) | 4-6 floods (recurring issue) | >6 floods (annual or near flooding) | 0 |
| **Presence of rivers, lakes, or coastline** | >20km away, low exposure | 10-20 km (low-moderate exposure) | 5-10 km (moderate) | <5km away (high exposure) | Within/adjacent to water body (extreme exposure) | 0 |
| **Drainage infrastructure quality** | Fully covered, modern, well-maintained system | Mostly covered, periodic maintenance | Mixed – some covered, clogging | Mostly open, poor maintenance | No drainage / frequently failing system | 0 |
| **Topography (low-lying, flat areas)** | Hilly / Sloping | Gentle undulations | Flat/ not low-lying | Partially low-lying, likely water stagnation | Fully low-lying – major flood accumulation zone | 2 |
| **Soil permeability** | Very Highly permeable | Highly Permeable | Moderately Permeable | Poorly Permeable | Impermeable | 4 |
| **% of Forest Cover** | >40% green cover | 30-40% green cover | 20-30% green cover | 10-20% green cover | <10% green cover | 3 |
| ***Total Score for Floods*** | | | | | | **2** |

[66] The template uses a hypothetical "City A" as an example; however, it is applicable to risk assessments for any Indian city.

| *Hazard Analysis for a City* | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low** | **Low** | **Moderate** | **High** | **Very High** | **City A** |
| | **0** | **1** | **2** | **3** | **4** | |
| **2. Earthquakes** | | | | | | |
| **Proximity to fault lines and seismic zones** | Located in Zone II, far (>200 km from active fault lines) | Zone II but within 100-200 km from fault lines | Located in zone III (moderate risk) or 50-100 km from fault lines | Located in zone IV (high risk) or within 50km of active fault | Located in zone V (very high risk) and/or sits directly over <25km from active fault lines | 0 |
| **Soil type (soft soils amplify shaking)** | Hard rock, well compacted gravel | Moderately dense soil with low potential for amplificatio n | Mix of soft and dense soils – moderate risks of amplification | Loose alluvium or reclaimed land | Deep soft, clay, riverine / alluvial plains – extreme amplification risk | 2 |
| **Historical earthquake activity- past 10 years** | No earthquakes recorded within 200 km | 1-2 minor tremors (less/equal to 3.5 magnitude) within 200km | 1 moderate earthquake (4.0-5.0) / 3+ minor tremors in 10 yrs. | Greater than /equal to 2 moderate or 1 strong earthquake (>5/6 magnitude) in last 10 yrs. | Recurring seismic activity with multiple moderate to strong quakes in past | 0 |
| ***Total Score for Earthquakes*** | | | | | | 1 |
| **3. Cyclones and Storms** | | | | | | |
| **Proximity to warm oceans or seas** | >500 km from sea | 250-500 km from sea | <250 km from sea, sheltered from cyclone (hills blocking the coastline) | <100km from open coastlines on By of Bengal, Arabian Sea | Coastal locations regularly impacted by cyclones | 0 |
| **Topography (flat coastal areas are most vulnerable)** | Hilly terrain, elevation >100m, minimal cyclone impact | Undulating terrain, elevation - 50-100 m | Gently sloping areas, elevation – 20-50m | Flat terrain, elevation - | Flat, low-lying terrain less than/equal to 10m with coastal exposure | 1 |

| Hazard Analysis for a City | | | | | | |
|---|---|---|---|---|---|---|
| Hazard Scoring | Very low | Low | Moderate | High | Very High | City A |
| | 0 | 1 | 2 | 3 | 4 | |
| **Historical cyclone landfalls and tracks- past 10 years** | No cyclones within 200 km in past 10 yrs. | 1 cyclone within 200km | 2-3 cyclones within 100-200 km | More than 2 landfalls within 100km in last decade | Regular / bi-annual landfalls within 100 km | 0 |
| **Wind patterns and monsoon behaviour** | Located in wind-sheltered zone, low speed monsoon winds | Minor exposure to monsoon or easterly winds | Moderate exposure to shifting monsoon winds | Consistent exposure to high winds from southwest/ northeast monsoon | Region experiences intense gusts / cyclonic winds during every monsoon or pre-monsoon season | 0 |
| ***Total Score for Cyclones*** | | | | | | **0** |
| 4. **Extreme Temperatures** | | | | | | |
| **Historical temperature extremes in last 10 years** | No days with temperature > 40°C or temperature < 10°C | 1-2 extreme days- heat or cold in 10 years | 1-2 extreme days every 3/5 years | 1-2 events annually | > 2 events annually | 0 |
| **Latitude and altitude (influence temperature)** | High (>1500 m), tropical coastlines with stable climate | Highland cities (1000 m-1500 m), latitude <10 degrees or >28 degrees | Mid-altitude (500-1000m) or sub-tropical zones (10-25 degrees altitude) | Latitude 20-30 degrees, lowland terrain, elevation <500m | Hot interior plains | 3 |
| **Urbanization level (urban heat island effect)** | Rural/agricultural with <10% BUA | Small towns/peri-urban zones with 10-30% urbanization | Emerging cities or mid-size towns (30-60% BUA) | Large cities (>60% BUA) with traffic, concrete concentration | Dense metro areas (>80% BUA) | 3 |
| **Vegetation cover (green spaces mitigate heat)** | >50% | 35-50% | 20-35% | 10-20% | <10%, fully built-up area | 1 |
| ***Total Score for Extreme Temperatures*** | | | | | | **2** |

| ***Hazard Analysis for a City*** | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low** | **Low** | **Moderate** | **High** | **Very High** | **City A** |
| | **0** | **1** | **2** | **3** | **4** | |
| **5. Battery Fire and Thermal Runaway** | | | | | | |
| **Historical incident rate- for e-bus model/ OEM** | No reported incidents | 1-2 incidents over 3/5 years | Known history of thermal incidents | Frequent fire related incidents | Mass replacements due to heavy risks | 0 |
| **Charging infrastructure reliability** | Charger uptime, > 97% AMC in place, BIS certified chargers | Minor delays or connector mismatches | Regular faults requiring manual resets | Failures during peak demand hours | Frequent trips due to capacity overload | 0 |
| **Frequency of maintenance of chargers** | Weekly | Biweekly | Monthly | Quarterly | Annually | NA |
| **Age of fleet and frequency of maintenance** | <1 yr. old, under warranty with OEM support and predictive maintenance | 1-3 years with timely replacement and maintenance | 4-6 yrs. with observed performance deterioration | 6-7 yrs. with minimal battery health tracking, and no maintenance | >7 yrs., untracked battery degradation, warranty expired and no maintenance | 2 |
| ***Total Score for Battery Fire & Thermal Runaway*** | | | | | | **1** |
| **6. Power Failure and Grid Instability** | | | | | | |
| **Local grid reliability** | Smart grid systems, <2 outages per year | Stable grid with <5% downtime | Outdated, voltage fluctuation incidents | Failure of transformers in depots | Backouts due to excessive load, no power backup, regular grid collapse | 0 |
| **Frequency of load shedding** | 1 incident annually | 1 event in 2- 3 months | 1 event every month | 1 event every weak | 1 event everyday | 0 |
| ***Total Score for Power Failure & Grid Instability*** | | | | | | **0** |
| **7. Cyber Threats to Depot Management Systems** | | | | | | |

| *Hazard Analysis for a City* | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low** | **Low** | **Moderate** | **High** | **Very High** | **City A** |
| | **0** | **1** | **2** | **3** | **4** | |
| **Past incidents of cyberattacks** | None reported on fleet systems. OEM platforms | Rarely since operations (1-2 no's) with no operational impact on buses | Known cyber breach, affecting apps, GPS, payment systems in the city earlier | Direct incidents on e-bus ecosystem (depot management system, charger control, GPS spoofing etc.) or SCADA | Repeated attacks with successful access to depot control systems, ransomware in depot SCADA, large scale data leaks, system shutdowns causing bus downtime | 0 |
| **Charger communication protocol/ CAN data/ GPS data** | Encrypted CAN, isolated GPS | Minor anomalies with spoofing blocked | CAN data anomalies or GPS misalignment | Past spoofing or protocol breach | Charger / system disabled due to spoofing | 0 |
| **Third party vendor risks** | Fully certified vendors with strong IT security practices | Basic security compliance by vendors | Known third party software vulnerabilitie s | Past incidents involving third-party breaches | Repeated or active vendor side exploitation | 0 |
| **Level of Internet connectivity and remote access to e-bus depot management systems** | Use of isolated, restricted network by depot management and energy control systems with 2 FA access | Admin access via private IP, regular audits, and checks, only OEM and depot manager have login rights | Web portal with open access ports or shared credentials, no audit trail logs maintained | Malware / phishing incidents affecting operations | Major shutdowns due to system compromise – depot access disabled, buses misrouted / halted, system encrypted etc. | 2 |
| ***Total Score for Cyber Threats*** | | | | | | **1** |
| **8. Technological Obsolescence** | | | | | | |
| **Past incidents related to technological obsolescence of** | No significant history of obsolescenc e across | Minimal history of obsolescen ce issues; | Some component-level obsolescenc | At least one major obsolescence incident | Multiple incidents in the past where major | 0 |

| ***Hazard Analysis for a City*** | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low** | **Low** | **Moderate** | **High** | **Very High** | **City A** |
| | **0** | **1** | **2** | **3** | **4** | |
| **e-bus components** | critical components | only minor software or component discontinuations with easy alternatives available | e cases but manageable through OEM support | requiring costly retrofits or replacements | components (battery, chargers, drivetrain, control systems) became obsolete | |
| **Battery Technology Maturity & Upgrade Compatibility** | Uses state-of-the-art, future-ready chemistry with modular, upgradeable design | Uses relatively advanced chemistry with moderate upgrade pathways; retrofit partially feasible | Some scope for upgrades but may need high-cost interventions | Current battery chemistry widely used today but facing rapid phase-out trends; limited retrofit options | Uses outdated/legacy chemistry with no upgrade or retrofit path; high likelihood of early obsolescence | NA |
| ***Total Score for Technological Obsolescence*** | | | | | | **0** |
| **9. Protests, Strikes and Vandalism** | | | | | | |
| **Local socio-political stability** | Stable governance and regulatory eco system for e buses, strong public support for transport reforms | 1/ 2 minor incidents in past 5-10 years, low public opposition to fare/ route changes, no recent unrest affecting bus operations | Periodic protests over fare hikes, minor cases of vandalism during strikes, moderate criticism of e-bus reliability | Frequent delays or operational disruptions, known history of civil unrest | Ongoing protests, vandalism, regular service disruptions | 1 |
| **Public perception of transport services or government policies (fare hikes, layoffs)** | High public approval of e-buses, transparent / participatory policy decisions | Isolated fare revision protests, minor dissatisfaction over | Periodic complaints over bus availability, wait times – fare hikes, layoffs, bad | Frequent dissatisfaction in feedback surveys, opposition to fare revisions, drivers' layoffs | Ongoing public unrest and campaigns against bus operators, viral incidents of accidents / | 0 |

| Hazard Analysis for a City | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low** 0 | **Low** 1 | **Moderate** 2 | **High** 3 | **Very High** 4 | **City A** |
| | (fare, routes), no fare hikes in the past | quality of service, | media publicity | | poor service, strong media criticism | |
| **History of strikes/ vandalism events** | 1 event in past 10 years | 1 event every 2-3 years | 1 event every year | 2-3 events every year | 1 event every 2-3 months | 0 |
| ***Total Score for Protests & Strikes*** | | | | | | **0** |
| **10. Traffic and Operational Accidents** | | | | | | |
| **Historical accident rates** | No major road accidents involving e-buses, comprehensive driver training, advanced ITS systems in place | 1-2 minor accidents annually, good accident response system, Depots follow SOPs strictly | Periodic low-severity accidents due to road conditions, technical glitches like brake failure, door sensors etc. | Frequent accidents due to poor training – inadequate depot design or power surges, brake failures and short circuits | Recurring incidents – systematic neglect in driver certification, multiple depots and on-road accidents reported | 1 |
| **Driver shift lengths and fatigue risk (long working hours)** | Adherence to standard 8-hour shifts with breaks | Isolated cases of overwork, but monitored | Long shifts common during festivals, holidays, driver fatigue suspected in delays | Shift overruns due to staff shortages – health complaints among drivers due to extended hours | Chronic overwork (>10/12-hour shifts) – multiple incidents linked to fatigue, microsleep episodes | 0 |
| **Complexity of road and depot manoeuvres (tight spaces, blind spots)** | Spacious modern depots with clear signage | Some tight roads but manageable- minimal depot congestion | Complex routes, depot design not fully suited for 12m buses | Frequent driver error during parking/ exit repeated near misses/ minor collisions at depots | Systematic depot congestion, blind spots, and cramped conditions | 0 |
| ***Total Score for Traffic & Operational Accidents*** | | | | | | **0** |

| ***Hazard Analysis for a City*** | | | | | | |
|---|---|---|---|---|---|---|
| **Hazard Scoring** | **Very low** | **Low** | **Moderate** | **High** | **Very High** | **City A** |
| | **0** | **1** | **2** | **3** | **4** | |
| **11. Human Negligence** | | | | | | |
| **Workforce size and turnover rate** | Stable workforce with attractive wages and working conditions | Isolated resignations or transfers, efficient hiring | Periodic shortages in staffing | High resignation rate due to job stress, chronic understaffing | Inability to run services due to understaffing | 0 |
| **Presence of SOPs** | All SOPs documented, displayed, and practiced | SOPs present but under periodic review | SOPs exist but not enforced, depot level variations in awareness | Outdated SOPs or ignored by the staff, lack of procedural clarities | No SOPs available, all operations based on informal practices | 0 |
| **Training** | Structured mandatory staff training – simulator based or on-field modules | Training programs run but refresher modules are infrequent | Only onboarding training provided, few skill enhancement sessions now-and-then | Ad hoc training, not standardized, staff report inadequate preparation | No formal training staff learn on the job without manuals or guidance | 0 |
| **Workplace Stress Factors (long shifts, lack of resting space etc.,** | Rotational shifts with adequate rest, | Slight delays during peak hours, few stresses related complaints | Pressure to meet ridership/frequency targets – drivers occasionally skip breaks | Extended shifts, strict turnaround deadlines- multiple complaints of stress and fatigue | Burnout level stress across staff, strikes or absenteeism linked to working conditions | 0 |
| ***Total Score for Human Negligence*** | | | | | | **0** |

The findings of the above analysis are summarised in the table below.

| Hazards | Hazard score | Likelihood and intensity |
|---|---|---|
| Floods | 2 | Moderate |
| Earthquakes | 1 | Low |
| Cyclones and Storms | 0 | Very Low |
| Extreme Temperatures | 2 | Moderate |

| | | |
|---|---|---|
| Battery Fire and Thermal Runaway | 1 | Low |
| Power Failure and Grid Instability | 0 | Very Low |
| Cyber Threats | 1 | Low |
| Technological Obsolescence | 0 | Very Low |
| Protests, Strikes and Vandalism | 0 | Very Low |
| Traffic and Operational Accidents | 0 | Very Low |
| Human Negligence | 0 | Very Low |

### Step 2: Exposure analysis

After deriving the city-level hazard score, the analysis zooms in to depot level exposure analysis. In this step a detailed assessment of exposure of an e-bus depot in the city was conducted based on the primary data received through consultation with public bus agency. The assessment is captured in table below.

| Exposure Analysis for Depots | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Not exposed** | **Slightly Exposed** | **Moderately Exposed** | **Highly Exposed** | **Extremely Exposed** | **Depot A** |
| | **1** | **2** | **3** | **4** | **5** | |
| **Number of E-buses in a depot** | <50 | 50 to 75 | 75 to 100 | 100 to 150 | >150 | 1 |
| **Number of Staff per depot (technicians, supervisors, charging operators, cleaning staff)** | <30 | 30-50 | 50-75 | 75-100 | >100 | 3 |
| **Facility Size and Built-up Area (sq. m.)** | <3000 | 3000 to 10000 | 10000 to 15000 | 15000 to 30000 | >30000 | 3 |
| **Total number of chargers** | 10 to 13 | 17 to 20 | 22 to 25 | 35 to 38 | 40 or more | 1 |
| **Percentage of fast chargers/ depots** | <10% | 11% to 25% | 26% to 50% | 51% to 75% | 76% or more | 1 |
| **Number of spare HV batteries (If applicable)** | 0 - 2 | 3 to 4 | 5 to 7 | 8 to 10 | >10 | NA |
| **Number of Transformers (step down)** | 1 to 2 | - | - | - | > 2 | 1 |
| **Number of substations providing electricity connection** | 1 to 2 | - | - | - | > 2 | 1 |

| Exposure Analysis for Depots | | | | | | |
|---|---|---|---|---|---|---|
| Parameters | Not exposed | Slightly Exposed | Moderately Exposed | Highly Exposed | Extremely Exposed | Depot A |
| | 1 | 2 | 3 | 4 | 5 | |
| Length of cabling from Substation to Depot | < 2 Km | 3 to 5 km | 6 to 8km | 8.1 – 10 km | > 10 km | 3 |
| Proximity of the critical land use to affected depot (in km) | > 5 km | 3 – 4 Km | 2 – 3 km | 1 - 2 km | < 1 Km | 3 |
| Daily E-bus ridership per depot | < 10000 | 50000 | 100000 | 150000 | >150000 | 2 |
| Number of drivers and conductors on route | <100 | 100 to 3400 | 3401 to 6700 | 6701 to 10000 | >10000 | 2 |
| Number of bus stops on routes assigned to the depot | <50 | 50 to 1200 | 1201 to 2350 | 2351 to 3500 | >3500 | 2 |
| *Exposure Score for a Depot* | | | | | | *2* |

The average exposure score for identified e-bus depot A is found to be 2.

**Step 3: Vulnerability Analysis**

Detailed vulnerability analysis of the identified e-bus depot in Indian City A was performed based on the parameters detailed out in chapter 3. A detailed input was received through primary consultation with public bus agency.

| Vulnerability Scores for a Depot | | | | | | |
|---|---|---|---|---|---|---|
| Vulnerability parameters | Not Vulnerable | Slightly Vulnerable | Moderately Vulnerable | Highly Vulnerable | Extremely Vulnerable | Depot A |
| | 1 | 2 | 3 | 4 | 5 | |
| % buses with battery SOH< 80% | <10% | 10% to 25% | 25% to 50% | 50% to 75% | >75% | 1 |
| Presence of onboard fire safety systems | FDSS+ FAS + FPS (In engine and passenger compartment) | FDSS+ FPS (in Passenger Area) | FDSS+ FAS (in Passenger Area) | FDAS (Passenger Compartment only) | FDAS (Engine Compartment only) | 4 |
| Ingress protection standard of e-bus fleet | Greater than IP 67 (e.g. IP 68 or IP 69K) | - | IP 67 | - | Lower than IP 67 | 3 |
| Real-time monitoring of batteries using BMS | Available | - | - | - | Not available | 1 |

| Vulnerability Scores for a Depot | | | | | | |
|---|---|---|---|---|---|---|
| **Vulnerability parameters** | **Not Vulnerable** | **Slightly Vulnerable** | **Moderately Vulnerable** | **Highly Vulnerable** | **Extremely Vulnerable** | **Depot A** |
| | **1** | **2** | **3** | **4** | **5** | |
| **Availability of driver's console for communication and monitoring of vehicle** | Available | - | - | - | Not available | 1 |
| **Frequency of maintenance of e-buses** | Twice a week | Weekly | Bi-weekly | Monthly | Quarterly | 1 |
| **Time taken to rectify identified defects & deficiencies in fleet** | Daily | Weekly | Bi-weekly | - | - | 1 |
| **Availability of alternate route plan for e-buses during emergency situations** | Available | - | - | - | Not available | 1 |
| **Type of depot** | Only e-bus depot | - | - | - | Hybrid Depot | 1 |
| **Age of chargers (in years)** | <2 | 2 to 5 | 5 to 7 | 7 to 10 | >10 | 2 |
| **Ratio of monitoring personnel per depot (including night shifts)** | 1 personnel for 10 buses or less | - | 1 personnel for 10 to 15 buses | - | 1 personnel for 15 buses or more | 3 |
| **Clearance from Fire Department for the e-bus depot** | Involvement of fire department in depot planning | - | - | - | No Objection Certificate from Fire Department | 1 |
| **Clearance from explosive department for the e-bus depot** | Yes | - | - | - | No | 5 |
| **Compliance of e-bus terminals and bus stops with fire safety standards** | Comply with all of these | - | Comply with some of these | - | No compliance | 1 |
| **Dedicated zone for faulty e-buses** | Physical separation with fire resistant material | Physical separation but no fire-resistant material | Dedicated zone but no structural separation | No dedicated zone but spatial separation btw 5-10m | No dedicated zone | 4 |
| **Presence of multiple entry/exits and evacuation signages** | Yes | - | - | - | No | 5 |
| **Presence of early warning systems for potential natural hazards** | SMS alerts (IMD/ NDMA/ SDMA) and Weather Forecasting Device | - | One of the early warning systems is present | - | Absent | 5 |

| Vulnerability Scores for a Depot | | | | | | |
|---|---|---|---|---|---|---|
| **Vulnerability parameters** | **Not Vulnerable** | **Slightly Vulnerable** | **Moderately Vulnerable** | **Highly Vulnerable** | **Extremely Vulnerable** | **Depot A** |
| | **1** | **2** | **3** | **4** | **5** | |
| **Presence of depot level fire detection and suppression systems** (*smoke detectors, fire extinguishers, automated water sprinklers, fire hydrants*) | Both detection and suppression systems available | - | Only detection or suppression systems available | - | None of them are available | 1 |
| **Presence of safety equipment** *(PPE, lockout/tagout procedures, specialized tools for working on high-voltage systems*) | All of them are available | - | - | - | None of them are available | 1 |
| **Use of armoured and color-coded cables** *(connection from substation to meter to transformer to chargers)* | Available | - | - | - | Not Available | 1 |
| **Presence of real-time monitoring system for electricity fluctuations** | Available | - | - | - | Not Available | 5 |
| **Safety Requirements (Grounding, surge protection, and insulation quality)** | Available | - | - | - | Not Available | 1 |
| **Presence of more than 1 grid connection** | > 1 grid connection with adequate RE Storage | > 1 grid connection with limited backup | > 1 grid connection | single grid connection with limited backup | single grid connection without backup | 5 |
| **Frequency of repair and maintenance of charging stations** | Monthly | Quarterly | Half-yearly | Yearly | In more than a year | 1 |
| **Frequency of maintenance of transformers and cabling** | Monthly | Quarterly | Half-yearly | Yearly | In more than a year | 1 |
| **Frequency of third-party safety audit of e-bus depot** | Quarterly | Half yearly | Annually | Every two years | No Third-Party Auditing | 2 |
| **SoPs for handling, operating, and maintaining charging infrastructure** | Available | - | - | - | Not Available | 1 |
| **SoPs for emergency power cutoff at transformer level** | Available | - | - | - | Not Available | NA |

| Vulnerability Scores for a Depot | | | | | | |
|---|---|---|---|---|---|---|
| **Vulnerability parameters** | **Not Vulnerable** | **Slightly Vulnerable** | **Moderately Vulnerable** | **Highly Vulnerable** | **Extremely Vulnerable** | **Depot A** |
| | **1** | **2** | **3** | **4** | **5** | |
| **Evacuation Plan for depot staff and buses for various hazards** | Available | - | - | - | Not Available | NA |
| **Evacuation protocols or guidelines for on-board passengers** | Available | - | - | - | Not available | NA |
| **Frequency of Refresher Driver Trainings** | Monthly | Quarterly | Half-yearly | Yearly | In more than a year | 1 |
| **Frequency of Emergency response trainings for drivers and conductors** | Monthly | Quarterly | Half-yearly | Yearly | Only at the time of induction | 1 |
| **Frequency of Emergency response trainings for depot staff and STU officials** | Monthly | Quarterly | Half-yearly | Yearly | Only at the time of induction | 5 |
| **Inclusion of E-bus related hazards in state/district-level disaster management plans** | Included | - | - | - | Not included | 5 |
| **Coordination protocols between city disaster management officials and transit authorities** | Available | - | - | - | Not available | 1 |
| ***Total Vulnerability Score for a Depot*** | | | | | | **2** |

Based on the above assessment, the average vulnerability score for the e-bus depot is derived to be 2.

### Step 4: Consequence Analysis

As a next step, consequences scores of components will be calculated basis the exposure and vulnerability scores calculated above. The formula mentioned in section 3.3 will be used to calculate the consequence scores. In case of Bhubaneswar, the weightages recommended by the procedure of 70 % for exposure and 30% for vulnerability is considered. Final consequence score is computed to be 2.

| Input for Consequence analysis | Depot A |
|---|---|
| Exposure Score for a Depot | 2 |
| Total Vulnerability Score for a Depot | 2 |
| Weightage of Exposure | 70% |
| Weightage of Vulnerability | 30% |
| **Consequence Score** | **2.02** |

**Step 5: Deriving the Risk Score for various Hazards**

Risk score is a function of city-level hazard score and depot level consequence score. The detailed illustration of flood risk score for Gadkana depot is as follows:

***Flood Risk score = 2 (hazard score) * 2 (consequence score)***

***Flood Risk score = 4***

Based on the scaling indicated in the adjacent table, it is observed that the **flood risk for the depot is very low.**

| Legend | |
|---|---|
| **Risk Level** | **Risk Scores** |
| **Very Low Risk** | 1 to 4 |
| **Low Risk** | 5 to 8 |
| **Moderate Risk** | 9 to 12 |
| **High Risk** | 13 to 16 |
| **Very High Risk** | 17 to 20 |

An e-bus system level assessment for the selected city or STU or assessment of risk associated with specific private operator's depots can also be derived using this framework. As illustrated, the risk scores of the individual depots would be derived as a first step and they would be averaged to arrive at a system or operator level risk score.

## 14.2. Annexure B – Existing National and International codes related to EBES

| S.N. | DESCRIPTION | INDIAN STANDARDS | INTERNATIONAL STANDARDS |
|---|---|---|---|
| 1. | Bus body design codes | Compliance with latest CMVR, AIS 052, UBS II | IEC 62196; UNECE R107, R66, R95, R29 |
| 2. | Approval requirements for Electric Power Train Vehicles | AIS 038, AIS 049 | UN ECE R100 |
| 3. | Performance test and standards for braking | IS 17855 (Part 2) | - |
| 4. | Fire Safety Codes for Bus | AIS 153 | FMVSS 302; FMVSS 305 |
| 5. | Standards for traction batteries for Battery operated vehicles | AIS 048, AIS156 | ISO 6469; IEC 62660 – 2; LiFePO4 – UN Manual Test Sub Section 38.3; IEC 62840 |
| 6. | Standards for testing and safety of Lithium-Ion Batteries | - | SAE J2464; SAE J2380-2021; SAE J2929-2013; |
| 7. | Recommended Practices for Transportation & handling of Batteries | - | SAE J2950-2020; SAE J2936-2025 |
| 8. | Fire safety detection and suppression codes for the bus | AIS 135 | UNECE R100; EN 1839; |
| 9. | Safety Standards for Charging Requirements | AIS 138; IS 17017; MOP Guidelines; IS 2026; | IEC 61851 – 22/23; IEC 61851–24/23; IEC 61851-21/1:2001; IEC 609473; IEC 61557; IEEE 519; IEC 60076 |
| 10. | Inductive Charging System Standards | - | IEC 61980; ISO 19363; SAE J1773; |
| 11. | Vehicle- to- Grid communication interface (EV and EVSE) | IS 15118 | En ISO 15118-3 |

| | | | |
|---|---|---|---|
| 12. | Standard for the Installation of Stationary Energy-Storage Systems (ESS) | - | NFPA 855; |
| 13. | Safety Requirement from Electrical Hazards / Electrical Installations | IS 1646:1997 | NFPA 70; |
| 14. | Dust and Water Ingress protection | IP 67 - 68 | IEC 60529; |
| 15. | Guidelines for the selection, installation & maintenance of fire extinguisher / Fire Frightening System | IS 2190:2010; IS 5290; IS 15105:2002; IS2190; National Building Code Part IV; IS 908 | NFPA 10; NFPA 13 |
| 16. | Fire Detection and Alarm System in the buildings | IS 2189:2008 | NFPA 72 |
| 17. | Safety & Performance requirements for BMS | IS 17387:2020 | - |
| 18. | Code of practices for cables and earthing protection | IS 3043; IS732; IS 5312 | IEC 60364 – 54; IEC 61950; NFPA - 77 |
| 19. | Guide for Performing Arc Flash Hazard Calculations | - | IEEE 1584; |
| 20. | E-Bus Depot Planning and Guidelines | MoHUA – Manual for planning, designing, city bus depot 2020; | - |
| 21. | Standards for occupational health and safety | - | OHSAS 18001:2007 |

## 14.3. Annexure C – Details of available standards for E-Buses

Safety Standards of Battery E-Buses (BEBs) are generally governed by ISO, IEC, SAE, UN/ECE and the US- FMVSS standards. Also, the AIS and the BIS standards cover some of the safety requirements of BEBs. Some of these standards are captured here-under.

| Sr. No | DESCRIPTION | TECHNICAL SPECIFICATION |
|---|---|---|
| 1. | Bus Structural Integrity | AIS 052 and UBS II annexure 3, UN ECE R66, FMVSS 227 |
| 2. | Side Collision Protection | UNECE 95 / FMVSS 214 |
| 3. | Front Collision Protection | UN ECE 29 / FMVSS 208 |
| 4. | Roll Over Protection | AIS 052/ UBSII |
| 5. | Test for Structural integrity and vibrations affecting bus occupants | AIS 153 / ISO 16750-3:2012 |
| 6. | Safety standard for e-bus structural integrity in rollover accidents | UNECE R 66 / FMVSS 227 |

| | | |
|---|---|---|
| 7. | Electric Propulsion system & its requirement<br>i. Safety requirement of Traction batteries<br>ii. Type approval for Battery Propelled Vehicles | i. AIS:048<br>ii. AIS:049<br>(*As amended from time to time) |
| 8. | Construction and Safety Requirement of Battery | AIS:038 Rev-02<br>(*As amended from time to time) |
| 9. | Battery cooling system | Liquid cooling system: battery temperature to be maintained between 5 – 45 degrees Celsius. |
| 10. | Battery Life | Operator to replace the battery when state of health of battery falls below 80%. |
| 11. | Test Procedures for Li-Battery Packs | ISO-1240-1 & 2, 2011 & 2012 |
| 12. | Safety Specification of Re-chargeable Electric Energy Storage System (REESS) | ISO 6469 2012 |
| 13. | Battery Packs Impact Testing such as during a crash & or while negotiating pot- holes etc | SAE - 2464 |
| 14. | Battery Packs testing under vibrations | SAE J 2380 2021 |
| 15. | Safety Standard for Li-Battery | SAE J 2929 - 2013 |
| 16. | Provision of Circuit Breakers-Switched Protective Earth Portable Residual Current Devices | IEC 62335: 2008 |
| 17. | Recommended Practice for Transportation and Handling of Li based traction battery system | SAE J 2950 - 2020 |
| 18. | Life Cycle Testing of Battery module – performance degradation as function of life and identification of failure mechanism | SAE J 2020 |
| 19. | Safety requirements for Battery Swap System -- General Requirements and Guidance | IEC 62840 -1 & 2:2016 |
| 20. | Electric Drive Motors | Motor should be able to operate efficiently at ambient temperature of approximately (-20) to 50 degrees, humidity level from 5% to 100% with inbuilt protection for temperature rise beyond predefined levels. |
| 21. | **Battery Packs Power and Capacity be adequate to achieve:** | |
| | i. Acceleration (Meter / sec2) minimum | Greater than or equal to 0.8 |
| | ii. Bus Speed of 0-30 kmph in seconds | Less than or equal to 10.5 seconds |
| | iii. Minimum - Maximum Speed | Minimum - Maximum speed without speed limiter to be as per CMVR – 70 kmph +- 5 |
| | iv. Gradeability | As per UBS II |
| | v. Operating Range (AIS 040) | 240 kms for urban operations without any opportunity charging |
| | vi. Deterioration factor in range | <0.5% annually |

| | | |
|---|---|---|
| | vii. Net Power and max 30 minutes power | Measurement as per AIS041 |
| 22. | Allowed specific energy consumption of e-bus when tested as per AIS 039 (Latest revision) with AC switched on conditions (Annual Average) | 12m AC: 1.3 kWh/km<br>9m AC: 1.0 kWh/km<br>7m AC: 0.8 kWh/km |
| 23. | Brakes | Mandatory ABS with disc brake at front and rear.<br>In case of Brake failure provision should be made for obtaining effectiveness of service brakes.<br>Graduated hand controlled, spring actuated parking brakes acting on rear wheels. |
| 24. | Electrical system for auxiliary devices | 24V DC, 180 Ah |
| 25. | Batteries (ancillaries, equipment, and light and light signalling device) | Low maintenance type leads acid batteries for 24v & min 180ah system-performance as per BIS: 14257 – 1995 (latest) for 12-meter bus |
| 26. | Electrical Wiring & Control | It should as per the ITS specification and conforming to IP 67. It should be as per UBS – II and AIS: 153 |
| 27. | Speed Limiting device | AIS: 018/2001 or latest |
| 28. | Tyres | Steel Radial Tube-Less. Size and performance as per CMVR/IS. |
| 29. | Bus Gates/Doors (Passenger doors, drive door & emergency exit & Door) Ramp for wheelchair at the gates | 12m & 9M Bus: 2 Door<br>7m Bus: 1 Door<br>Driver door as per CMVR / AIS 052<br>Emergency Exits as per CMVR / AIS 052 & AIS 153 |
| 30. | Insulation: Roof and Side | FR Grade material glass wool, PU foam or thermocol; As per AIS 052 |
| 31. | Battery Pack Compartment | FR Grade material glass wool, PU foam or thermocol; As per AIS 052 |
| 32. | Corrosion Prevention & Painting | As per AIS 052 |
| 33. | Electrical System & Electrical Cable | As per CMVR, AIS 052 & AIS 153, shall be fire retardant conforming to IS:2465 – 1984 and quality marked. |
| 34. | Safety Requirement of electrical: Battery Cut – Off switch (Isolator Switch) | As per AIS 052<br>Battery Cut off (Total Three)<br>- One Manual near driver seat<br>- One Electronic on driver dashboard area<br>- One manual at the rear compartment<br>• (preferably near the battery) |
| 35. | ITS Enabled Bus | - Panic Button: Each row of the seat, as per AIS 140 specification<br>- The operator is required to share vehicle health monitoring and diagnostic (VHMD) parameters through the bus CAN data on a real time basis with the Centralized ITMS. The following CAN parameters should be integrated to the ITS and |

| | | |
|---|---|---|
| | | capable of transmitting data at a frequency of 30 sec to a centralized ITMS server. |
| 36. | Safety Related Items: Fire Extinguisher and automatic fire detection and suppression system | As per AIS 052 & AIS 153; compulsory provision of FDSS- in Traction Battery packs area; BMS; FPS in pax compartment |
| 37. | Life Cycle requirements of bus | 10 Years or 6,00,000 kms whichever is later.<br>OEM to take responsibility of bus bodies as well as of chassis for the period of warranty assured period. Operator to ensure refurbishment of vehicle after 6 years |
| 38. | Safety related warning labelling practice-- on components, sub-systems, and systems – Contents, placements, and durability through-out product life cycle i.e. initial use to disposal at End of Life (EOL) | SAE J 2936 2025 |
| 39. | Fire Detection & Alarm System (FDAS) | As per AIS 135 |
| 40. | Fire Detection & Suppression System as applicable to e-buses | UNECE R107 |
| 41. | Fire Alarm System for Battery Failure | UNECE R100 |
| 42. | Fire Retardancy | All bus body building material used inside the bus, should be fire retardant as per IS 15061:2002 |
| 43. | Flammability of internal materials standards | FMVSS 302 |
| 44. | Battery system integrity and protection against fire - Std | FMVSS 305 |
| 45. | National Fire Protection Association (NFPA) guidelines, for safe electrical installations and for energy storage systems including BEBs | National Electrical Code NFPA 70 and NFPA 855 respectively |

## 14.4. Annexure D – Details of available standards for Charging System

| **B1.** | **Conductive Charging** | |
|---|---|---|
| **1.** | The charging process regulations in manual connection for charging vehicles in depots. | IEC 61851-23,<br>IEC 61851-24, |
| **2.** | EV Conductive Charging System- General aspects | IEC 61851-1: 2017<br>IEC 61851-21:2001 |
| **3.** | High-level communication via the PLC (Power Line Communication) for cabling, CP contact pins – vehicles and chargers: | EN ISO 15118-3 for cabling, CP contact pin IEC 61851-23 (for vehicles) and<br>IEC 61851-24 (for chargers) |
| **4.** | EV Conductive Charging System- Charging Station AC / DC | IEC 61851 -22 / 23<br>OR<br>AIS 138 -Part 1 & 2 |
| **B2.** | **Inductive Charging** | |

| | | |
|---|---|---|
| **1.** | Standards and specifications for equipment required for the wireless transfer of electrical energy from the power grid to electric road vehicles | IEC 61980 |
| **2.** | Safety and interoperability requirements for on-board equipment enabling wireless transfer of magnetic field energy for charging electric vehicles | ISO 19363 |
| **3.** | Recommended practices on electric vehicle inductively coupled charging | SAE J1773 |
| **B3.** | **Energy and Power Quality Regulation** | |
| **1.** | Energy and Power Quality Regulation | European Std. EN 5016 |

## 14.5. Annexure E - Sample Post-Disaster Damage Assessment Format

**Form Name:** Post-Disaster Damage & Safety Assessment Form
**To be filled by:** Authorized Site Assessment Officer
**Time Window:** Within 6–12 hours of disaster occurrence

| ***Section*** | ***Details*** |
|---|---|
| ***Basic Info*** | |
| *Date & Time of Assessment* | DD/MM/YYYY - HH:MM |
| *Name & Designation of Assessor* | |
| *Depot / Charging Location / Route Segment* | |
| *Type of Event* | [] Earthquake [] Flood [] Fire [] Heatwave [] Protest [] Traffic Accident [] Human Negligence [] Grid Instability [] Battery Fire [] Cyber Attack [] Other (specify) |
| ***Fleet Assessment*** | |
| *Total No. of E-Buses on Site* | |
| *No. of Buses with Visible Damage* | |
| *Nature of Damage* | [] Structural [] Electrical [] Battery [] Tyre/Undercarriage |
| *Are Any Buses Unsafe to Operate?* | [] Yes [] No |
| *Recommended Action* | [] Isolate [] Send for Repair [] Clear for Operation |
| ***Depot/Infra Assessment*** | |
| *Building Condition* | [] Minor Cracks [] Major Cracks [] Roof Collapse [] Waterlogging |

| Section | Details |
|---|---|
| *Electrical Panels* | [] Exposed [] Wet [] Functional |
| *Fire Safety Systems* | [] Accessible [] Obstructed [] Depleted |
| *Admin/Control Rooms* | [] Functional [] Partially Functional [] Non-Functional |
| *CCTV & Security Systems* | [] Operational [] Offline [] Damaged |
| ***Charging Infra Assessment*** | |
| *Total Chargers On-Site* | |
| *No. of Non-Functional Units* | |
| *Power Supply Status* | [] Available [] Fluctuating [] Disconnected |
| *Risk of Electrocution or Short Circuit* | [] High [] Medium [] Low |
| *Communication System Status* | [] Online [] Offline |
| ***Operating Environment*** | |
| *Status of Bus Corridors* | [] Clear [] Debris Present [] Obstructed |
| *Support Infrastructure (Stops, Signage)* | [] Damaged [] Missing [] Intact |
| *Power / Comms at Major Junctions* | [] Operational [] Partial [] Down |
| ***Other Notes / Observations*** | e.g., oil leakage, debris, flooding, fallen trees, etc. |
| ***Assessor Signature*** | |

## 14.6. Annexure F - Post Disaster Hazard specific checklist

1. Floods/ Water logging

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Water ingress in batteries, electrical systems, cabin, and storage<br>• Test braking and steering systems for water damage<br>• Rust/corrosion signs in undercarriage and connectors |
| **Depot** | • Inspect electrical control rooms, substations, and wiring for short circuits<br>• Drain water, clean oil pits, and disinfect<br>• Damage to stored spare parts, diesel tanks (if hybrid) |
| **Charging Infra** | • Test chargers for moisture damage<br>• Ensure earthing, surge protection, and insulation is intact<br>• Clean connectors and recheck voltage output before resuming |

| Component | Post-Disaster Checklist |
| --- | --- |
| **Operating Environment** | • Assess road subgrade and surface damage<br>• Check water stagnation near bus stops, terminals<br>• Coordinate with drainage departments for future risk mitigation |

2. Heatwaves/ Extreme Temperature

| Component | Post-Disaster Checklist |
| --- | --- |
| **Fleet** | • Check battery thermal profiles and BMS logs<br>• Inspect HVAC systems and cabin insulation<br>• Monitor for overheating signs on high-temp days |
| **Depot** | • Inspect staff working areas for ventilation adequacy<br>• Ensure shaded parking, cool zones, and fans are operational<br>• Verify fire safety and emergency response equipment |
| **Charging Infra** | • Monitor heat damage to charging cables, terminals<br>• Review operational logs for charger overheating shutdowns<br>• Confirm air conditioning/cooling systems for chargers are functional |
| **Operating Environment** | • Check road surface integrity (melting asphalt, cracks)<br>• Ensure emergency water, first-aid, and heat protection gear at bus stops<br>• Assess traffic delays due to heat-related incidents |

3. Earthquake/ Landslides

| Component | Post-Disaster Checklist |
| --- | --- |
| **Fleet** | • Inspect vehicle structure, steering alignment, and suspension<br>• Ensure onboard electronics and displays are not shaken loose<br>• Check emergency egress functions and fire suppression systems |
| **Depot** | • Check building cracks, slab displacements, wall collapses<br>• Inspect underground storage, tanks, and pit alignment<br>• Test power supply and water pipelines for damage |
| **Charging Infra** | • Verify anchoring of chargers and switchboards<br>• Conduct safety test on transformers and power distribution units<br>• Inspect cable trays, junction boxes, and connectors |
| **Operating Environment** | • Evaluate road damage, slope stability, and risk of aftershocks<br>• Deploy traffic control if route sections are unusable<br>• Install warning signage and barriers as needed |

4. Battery Fire/ Explosion

| Component | Post-Disaster Checklist |
| --- | --- |
| **Fleet** | • Isolate affected vehicles immediately<br>• Inspect fire suppression systems<br>• Review battery management system logs and failure points |

| Component | Post-Disaster Checklist |
|---|---|
| | • Perform thermal imaging scan on nearby vehicles |
| **Depot** | • Assess fire spread, smoke damage, and ventilation<br>• Review placement of fire extinguishers and hydrants<br>• Check alarm and emergency alert systems functioned correctly |
| **Charging Infra** | • Examine charger casing, cooling system, and cable burns<br>• Test power supply stability and short-circuit protection<br>• Review fire origin to isolate systemic issue |
| **Operating Environment** | • Notify and reroute buses from affected routes<br>• Clean up smoke-damaged stations or infrastructure<br>• Coordinate with local emergency/fire departments for inspection |

5. Grid instability/ Power Outage

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Check if any battery malfunctions or communication losses occurred during outage<br>• Ensure power-dependent systems (HVAC, doors, telematics) are functional<br>• Update software logs for power cut response tracking |
| **Depot** | • Inspect UPS, backup generators for fuel levels and performance<br>• Test depot lighting, control systems post-outage<br>• Restart systems in phased manner to avoid surge overload |
| **Charging Infra** | • Review charger restart logs for incomplete sessions or faults<br>• Calibrate chargers and test voltage stability before resuming<br>• Inspect grid interface, breakers, and fuses for tripping/damage |
| **Operating Environment** | • Identify traffic disruptions due to signal blackout or ITS failure<br>• Coordinate with DISCOMs for outage reporting and future backup planning<br>• Assess impact on passenger information systems (PIS, AFC, GPS) |

6. Cyber Threat

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Scan vehicle software for unauthorized access or code<br>• Reset and patch onboard systems if breached<br>• Check GPS, telematics, and control software for anomalies |
| **Depot** | • Audit all access points and login logs<br>• Reset credentials and install patches<br>• Ensure firewall and endpoint protection are updated |
| **Charging Infra** | • Validate charger firmware integrity<br>• Reboot and test for secure remote access<br>• Block malicious IPs or access logs identified |

| | |
|---|---|
| **Operating Environment** | • Check ITS, CCTV, AFC systems for breach indicators<br>• Restore backup data and logs<br>• Inform cybersecurity agency or certifying authority for investigation |

7. Technological Obsolescence

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Assess onboard systems (BMS, Telematics, Software) for outdated firmware or unsupported versions<br>• Check compatibility of vehicles with current charging standards and depot systems<br>• Plan for software updates, retrofits, or phased replacement of obsolete fleet |
| **Depot** | • Review depot management systems (IT systems, SCADA, monitoring tools) for software obsolescence<br>• Assess compatibility with new fleet technologies and charging systems<br>• Identify need for system integration upgrades or replacements<br>• Evaluate vendor support and upgrade pathways for legacy infrastructure |
| **Charging Infra** | • Assess chargers for compatibility with latest charging protocols and standards<br>• Evaluate charging efficiency and downtime due to outdated systems<br>• Identify risks of interoperability issues with newer buses |
| **Operating Environment** | • Review operational software platforms (fleet management systems, scheduling tools) for outdated technology<br>• Assess integration gaps between old and new systems across fleet and depot<br>• Evaluate vendor ecosystem and transition strategy for new technologies |

8. Protest / Vandalism

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Inspect vehicles for window, light, or panel damage<br>• Secure missing or stolen components<br>• Review CCTV footage (if available) |
| **Depot** | • Assess perimeter fencing, locks, gate access<br>• Reinstall broken equipment or systems<br>• File police complaint and insurance claims |
| **Charging Infra** | • Check for severed cables, broken panels, or disabled screens<br>• Secure and test grounding, insulation, and alarms<br>• Document and photograph all damages |
| **Operating Environment** | • Replace broken signage, station furniture<br>• Clear debris and make environment safe for public access<br>• Reinforce law enforcement presence if needed |

9. Traffic & Operational Accidents/ Human Negligence

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Assess structural, suspension, and electrical damage<br>• Inspect safety systems - cameras, indicators, brakes<br>• Conduct accident root-cause analysis |
| **Depot** | • Evaluate impact on scheduling, vehicle deployment<br>• Conduct incident report and insurance processing<br>• Review driver training effectiveness |
| **Charging Infra** | • Check if crash occurred near charging points<br>• Verify if any pole, signage, or power systems were affected<br>• Test system for short-circuit or surge risk |
| **Operating Environment** | • Inspect site of accident for road repair needs<br>• Reassess speed limits and signage<br>• Coordinate with traffic police for improved safety |

10. Management Lapse

| Component | Post-Disaster Checklist |
|---|---|
| **Fleet** | • Review logs for driver errors, misuse of systems, or deviation from SOPs<br>• Inspect for improper battery charging, overloading, or operational misuse<br>• Conduct refresher training if patterns are observed |
| **Depot** | • Check shift logs, maintenance records for skipped tasks or errors<br>• Verify inventory handling (spare parts, fuel, chemicals) is proper<br>• Audit operational SOP adherence by staff and contractors |
| **Charging Infra** | • Inspect for manual override incidents or improper charging practices<br>• Review logs for skipped maintenance or software tampering<br>• Recalibrate or reset chargers as needed |
| **Operating Environment** | • Assess ITS, CCTV, and station safety protocols violated<br>• Verify if SOPs for passenger handling, emergency response were followed<br>• Document lapses and initiate disciplinary or corrective measures |

## 14.7. Annexure G– List of References


[1] Vahan Dashboard, MoRTH
[1] Source: Internal Discussions and Workshop Insights
[1] Zenobe - Electric bus battery degradation
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