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Enhancing Electric Vehicle Roadside Assistance in India: A Framework for Infrastructure, Skills, and Service Excellence

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Abstract- The rapid growth of the electric vehicle (EV) ecosystem in India has been driven by government initiatives, increasing environmental awareness, and declining battery costs. With EVs accounting for over 6.8% of new passenger vehicle registrations in 2024, the need for reliable support infrastructure, particularly Electric Vehicle Roadside Assistance (EV RSA), has become increasingly critical. Unlike internal combustion engine (ICE) vehicles, EVs experience unique breakdown scenarios such as battery depletion, charging system failures, and high-voltage safety issues, which conventional roadside assistance systems are often not equipped to handle. This study examines the operational challenges and service effectiveness of EV roadside assistance in India using a mixed-methods research design. Primary data were collected through 12 semi-structured in-depth interviews with RSA managers, EV original equipment manufacturer (OEM) representatives, field technicians, fleet operators, and EV users, complemented by a structured survey of 118 respondents. The study tested four hypotheses: (H1) infrastructure gaps negatively affect RSA efficiency; (H2) technician skill deficiencies increase service resolution time; (H3) faster RSA response times positively influence customer satisfaction; and (H4) high operational costs combined with low demand reduce the commercial viability of mobile EV charging services. The findings provide statistical support for all four hypotheses. Infrastructure inadequacy emerged as the most significant operational challenge (Mean = 4.21/5), with 73% of EV users expressing dissatisfaction with charging infrastructure accessibility during breakdown situations. Technician capability was identified as another major concern, as only 18% of RSA companies reported providing EV-specific high-voltage safety training. The average response time for EV breakdowns was 47 minutes, compared with 23 minutes for conventional ICE vehicles, and response time exhibited a strong negative correlation with customer satisfaction (r = -0.71). Furthermore, mobile EV charging services were found to be commercially unviable under current market conditions because of high deployment costs (approximately ₹18,000–₹28,000 per deployment) and low utilization rates. Based on these findings, the study proposes a Tier-Based EV Roadside Assistance Operational Framework that integrates technician certification pathways, intelligent dispatch systems, charging infrastructure mapping, service integration, and conditional deployment of mobile charging services. The paper also presents practical recommendations for OEMs, RSA providers, charging network operators, and policymakers to strengthen India's EV after-sales service ecosystem and support the sustainable adoption of electric mobility.

Keywords: Electric Vehicle, Roadside Assistance, EV Infrastructure, Skill Gap, Mobile EV Charging, Customer Satisfaction, India, Service Operations, Mixed Methods.

I. INTRODUCTION

The automotive industry in India is at a structural change point. The number of EV registrations increased by more than 78 times over a period of five years, i.e., FY 2020-FY 2024, to over 1.7 million units every year, whereas the compound annual growth rate was bigger than 78. Two-wheelers are the most common EVs, comprising almost 58% of total EV registrations, then three-wheelers (31) and passenger four-wheelers (11). Hastened by the Faster Adoption and Manufacturing of Electric Vehicles (FAME II) scheme, the Production Linked Incentive (PLI) scheme of the Advanced Chemistry Cell (ACC) batteries, and incremental state EV polices, this growth trend has fundamentally changed the mix of the Indians roads.

However, with India moving at a frightening pace to adopt EVs, one important aspect of the infrastructure has been largely ignored: the roadside support of electric vehicles. In the case of a failed petrol or diesel, the pathway to resolution is comparatively uniform: it is possible to ferry fuel, towing can be done universally and most mechanics have the fundamental skills necessary to diagnose and remedy the usual failure modes. Electric cars are on a different paradigm though. Battery management system failure, charger port failure, or an exhaust depletion of state-of-charge are difficult issues that cannot be handled by traditional RSA protocols.

The repercussions are not simply inconvenience as an operation. The bad RSA experience of EV users is becoming one of the primary EV adoption inhibitors, especially in the middle-income customer and fleet operator segments that are less risk-averse to operational risks. It has also been found by research conducted by the Society of Indian Automobile Manufacturers (SIAM) that after sales service confidence is the third most significant purchase criteria to potential EV buyers after range and price. RSA failure or unavailability also causes word of mouth corrosion, damages OEM warranty coverage, and reputational risk to the overall EV ecosystem.

The basis of this paper lies in a core knowledge gap in the academic literature and industry practice: the gap between the gap of the lack of an empirically motivated and structured comprehension of EV RSA challenges in the Indian context and the gap of the lack of a measurement framework that could overcome these challenges in an operational context. Although the world is replete with research about EV infrastructure, range anxiety, and charging network development, EV-specific RSA operations, especially in the emerging market setting, is a field of study that is massively under-researched.

Scope of the Study

The current investigation will concentrate on Tier-1 and Tier-2 Indian cities with the largest number of EVs but with a disorganized RSA infrastructure. It includes research on both two-wheeler and four-wheeler EV RSA operations, and discussion on whether mobile EV charging can become a service innovation, and a framework that can be applied to both OEM-led, aggregator-led and hybrid RSA model.

The Mobile EV Charging Question

Among the research questions that will distinguish this paper is owing to mobile EV charging-the idea of initiating vehicles with a charging unit on board to provide on-road power to stalled EV drivers. Although visually attractive (comparable to fuel jerricans in the case of ICE cars), mobile EV charging is highly complex operationally, technically and economically. This paper focuses on analyzing its feasibility as an empirical study based on qualitative and quantitative methods by using both expert interviews and user surveys and is one of the first studies of this kind to offer India-specific results of analyzing this service model.

II. LITERATURE REVIEW

We have divided the literature review into four thematic clusters that directly correspond to hypotheses of the study: EV infrastructure issues, workforce readiness and skill of the technicians, response time dynamics and the quality of the services, and new RSA models, such as mobile charging viability.

EV Infrastructure Challenges (H1)

Charging Infrastructure and Range Anxiety

Nilsson (2011) offered some of the early contributions to the range anxiety, by making it a psychologically multidimensional impediment to EV acceptance, rather than physical range constraints. The research results showed that perceived accessibility of charging infrastructure, rather than physical availability, plays a significant role in EV adoption. This is a key differentiating factor of RSA: the apparent availability of charging stations even in areas that have them might plummet in case of failure.

A thorough survey of the existing literature on the topic by Hardman et al (2018) on 57 studies on EV adoption in 14 separate countries determined that confidence in charging infrastructure, rather than vehicle range, is the most significant predictor of EV buying intentions among second-time buyers. What it means to RSA is that it has infrastructure related domains of service delivery (integration of real-time charging stations, proactive breakdown prevention):

it might be more effective than reactive RSA enhancements.

In an India-specific study commissioned by NITI Aayog, Chakraborty et al. (2019) mapped EV charging infrastructure previously-and currently-gaps in 13 states, finding that in metro cities, the average number of charging stations was 1 per 8 km2, whereas in Tier-2 cities, the average number of charging stations was 1 per 47 km2, which correlates to In their investigation.

Motoaki and Shirk (2017) have observed the reliability of charging stations under real-life conditions within the United States, as they discovered that about 22% of open charging session experiences involved the failure of the equipment, network problems, or user interface issues. When applied to the situation of India, where equipment maintaining standards are less standardized, the probability of failure is bound to be increased-worsening the demands of RSA.

The data of International Energy Agency (IEA, 2023) Global EV Outlook proves that the percentage of EVs to public charging points (namely, 22:1) in India is one of the highest in the Asia-Pacific region (China and South Korea have the percentages of 7:1 and 8:1, respectively), which implies structural infrastructure deficit, which directly impacts RSA networks.

Towing and Emergency Equipment Gaps

Green et al. (2020) analyzed the issue of EV towing in the UK post-market setting and concluded that about 38% of traditional tow trucks cannot tow vehicles with all-wheel drive or with any combination of regenerative braking set-up, exposing them to risks of damaging the engine-and-transmission components during transit. Such infrastructure gap is much more dramatic in India, where the penetration of flatbed towing among RSA providers is estimated to be at 23% (as compared to 67% in the UK). In an experiment on behalf of the US Department of Energy and its argonne national laboratory, Burnham et al. (2021) reported that inappropriate towing of EVs (especially those with permanently engaged electric motors) may result in severe and costly losses in the drivetrain, posing liability risks to RSA providers who are not prepared to adjust their equipment and protocols.

Technician Skill Gap and Workforce Readiness (H2)

Research by Mohanty et al. (2020) on infrastructure to vocational training of automotive technicians in the Indian Industrial Training Institutes (ITIs) revealed that by 2020, under 4 percent of ITI courses provided a curriculum specific to EVs. In the case of EV Skill Council of India, which was established in 2022, an estimated demand of 10 lakh EV-trained technicians by 2025 was designated against an actual trained workforce of less than 1.2 lakh, a demand-supply discrepancy of 8:1.

A study of workforce changes in the automotive service industry in Hawaii after initial EV adoption by Coffman et al. (2017) reported an aversion of Safety anxiety to high-voltage systems rather than a general lack of skills among technicians being a greater obstacle to business change than the skill gap itself. The psychosocial aspect of the skill issue applies to the Indian situation, with safety training facilities in its infancy.

The review of the EV technology challenges in urban settings by Sanguesa et al. (2021) reported high-voltage (HV) battery system diagnostics cannot be practiced without specialized equipment (HV-rated multimeters, insulation testers, BMS diagnostic software), which is not available in most independent service centers. An estimated cost of setting up a basic EV service bay was ₹8-12 lakh, which is prohibitive when small RSA operator are involved.

In their report on global aftermarket services, McKinsey & Company (2022) indicated that EV service operations demand almost half the different skill sets of ICE service-including power electronics, battery electrochemistry, software diagnostics, and protocols against HV hazards. This is why it is limited to OEM-certified service centers, only of which can be trusted to reliably fulfill such requirements without specific investment in staff development.

Rajput et al. (2023), In a study that is unique to RSA technician competencies in Maharashtra, 340 field technicians were surveyed, with only 14% having received any formal training on EV battery systems and 78% indicating that they were hesitant to approach EVs with suspicious BMS faults because of eyewave shock a risk, which has direct implications on the resolution time and service quality.

3.5 Identified Research Gap
The literature review indicates that, gaps exist in knowledge that are filled in this paper; they are:

- No detailed research has explored EV-specific RSA operation issues in the Indian market environment - the third-largest auto market and the fastest growing EV ecosystem globally.
- The current research on mobile EV charging viability is US- and Europe-based thus the available economic modeling of the task, as well as the willingness-to-pay statistics of the consumer in India, is not applicable to the Indian cost base and consumer profile.
- The interaction of skill deficiency of technicians, inadequacy in infrastructure and customer satisfaction in EV RSA has not been researched as a unity.
- No scalable, India-specific EV RSA working framework that integrates infrastructure, skill, technology, and service design dimensions have been reported in the literature..

In the paper, all four gaps are taken care of by primary data gathering, hypothesis testing, and framework creation.

III. RESEARCH OBJECTIVES AND HYPOTHESES

Research Objectives
The present study is guided by the following research objectives:

- The problem is to determine and examine the critical operation problem on EV roadside assistance in India.
- To test the effect of charging and towing infrastructure gaps on the efficiency of RSA services (H1).
- To determine the level of lack of skills in technicians and its effect on the time to resolve incidents(H2).

Hypotheses
The study formulates the following hypotheses to empirically examine the relationships identified in the objectives:

Hypothesis	Statement	Variable Type
H1	Infrastructure gaps (charging and towing) negatively impact EV RSA efficiency, leading to longer resolution times and lower service effectiveness.	H0: $r = 0$ | Ha: $r < 0$
H2	Technician skill deficiency significantly increases average incident resolution time in EV RSA scenarios.	H0: $r = 0$ | Ha: $r > 0$

IV. RESEARCH METHODOLOGY

The research design used in this study is an Exploratory-Descriptive Mixed Methods research design, which involves a combination of a qualitative depth and quantitative validation. The combined-methods design is suitable that the phenomenon (EV RSA in India is an evolving sphere of operations with not much prior data) is emergent and complex, there exists the need to produce both in-depth insights and generalisations, and the need to test causal hypotheses as well as develop theory based on the views of the participants.

Research Design
The overall research design is structured as follows:

Dimension	Choice	Rationale
Research Type	Exploratory + Descriptive	Phenomenon is emergent; requires both discovery and description
Approach	Mixed Methods (Qualitative dominant)	Depth from interviews, validation from survey
Qualitative Method	Semi-Structured In-Depth Interviews	Enables rich, industry-grounded insights
Quantitative Method	Structured Survey (Likert + MCQ)	Enables hypothesis testing at scale
Sampling (Qual.)	Purposive Sampling	Experts not accessible via probability sampling
Sampling (Quant.)	Convenience + Snowball	Rapid access to EV user population
Analysis (Qual.)	Thematic Analysis (Braun & Clarke, 2006)	Systematic, rigorous, reproducible
Analysis (Quant.)	Descriptive Stats + Pearson Correlation	Appropriate for Likert and continuous data

Quantitative Research Design

A questionnaire including 21 items in six sections was conducted online through Google Forms among 118 (130 sent to the respondents 12 of the questionnaires remained unanswered) valid respondents. The survey was focused on EV users (2W and 4W), with a second group of ICE users put into the survey to compare. They were divided into sections addressing:

- Respondent demographics
- Breakdown experiences
- Awareness and usage of RSA services
- Perception of infrastructure adequacy (H1)
- Perception of technician competence (H2)

V. QUALITATIVE FINDINGS: IN-DEPTH INTERVIEWS

5.1 Respondent Profiles

#	Name	Role	Organization Type	Experience
1	Rajiv Menon	RSA Operations Manager	Pan-India RSA Aggregator	14 years
2	Supriya Nair	EV After-Sales Head	EV 2W OEM	9 years
3	Deepak Agarwal	Senior RSA Technician	OEM-linked RSA (4W)	11 years
4	Mohammed Irfan	EV Fleet Manager	B2B EV Logistics Company	7 years
5	Ananya Krishnamurthy	EV Customer (4W Owner)	Tech Professional	3 yrs EV use
6	Prashant Vora	RSA Tech Lead	Insurance-linked RSA	17 years
7	Kavita Shetty	EV Policy Consultant	Industry Think-tank	12 years
8	Arjun Talwar	EV Service Engineer	EV OEM (4W)	6 years
9	Sunita Rao	EV User (2W, fleet)	Delivery Fleet Supervisor	2 yrs EV use
10	Manoj Patil	RSA Dispatcher	Independent RSA Operator	8 years
11	Vikram Singh	EV Infrastructure Analyst	Charging Network Company	10 years
12	Ritu Bansal	EV Customer (2W)	College Lecturer	1.5 yrs EV use

Quantitative Analysis: Survey Findings

Sample Demographics

A total of 118 valid responses were collected. The sample composition reflects the study's primary interest in EV users while including an ICE comparison segment.

Category	Segment	Count	Percentage
Age Group	Below 20	7	5.9%
	21-25	29	24.6%
	26-35	48	40.7%
	36-45	26	22.0%
	Above 45	8	6.8%
Vehicle Type	EV - 2 Wheeler	44	37.3%
	EV - 4 Wheeler	31	26.3%
	Both EV & ICE	18	15.3%
	Only ICE	25	21.2%
Usage Type	Personal	89	75.4%
	Commercial/Fleet	29	24.6%
Breakdown Experience	Yes - had breakdown	87	73.7%
	No breakdown	31	26.3%
RSA Awareness	Yes	98	83.1%
	No	20	16.9%
RSA Usage	Yes	63	53.4%
	No	55	46.6%

5.2 Descriptive Statistics: Core Variables

Variable	Question	Mean	Std Dev	Interpretation
Infrastructure (H1)	Q9: Charging stations accessible in emergencies	2.18	0.91	Strongly inadequate
	Q10: EV towing easily available	2.04	0.87	Very low availability
	Q11: Infra gaps create difficulties (reverse)	4.21	0.74	Strongly agreed
Skill (H2)	Q12: Technicians well-trained for EV	2.31	0.94	Largely untrained
	Q13: Confidence in roadside safety	2.47	0.89	Low confidence

Hypothesis Testing

H1: Infrastructure Gaps vs. RSA Efficiency

The composite infrastructure gap score was obtained (Q9+Q10, reverse-scored) and linked to the efficiency of RSA (proxy: inverse of self-reported resolution satisfaction). The Pearson correlation analysis gave:

Statistic	Value	Interpretation
Pearson r	-0.68	Strong negative correlation
p-value	< 0.001	Statistically significant ($\alpha = 0.05$)
r^2	0.46	Infrastructure explains 46% of efficiency variance
Decision	Reject H0	H1 Supported

Interpretation: The more gaps in infrastructure (reduced availability of charging stations and reduced towing support) the less efficient RSA can be. The high explained variance (r 2 = 0.46) and the strong correlation (r = -0.68) implies that the overwhelming factor that causes degradation in RSA performance is infrastructure. H1 is accepted.

H2: Technician Skill Deficiency vs. Resolution Time

Skill deficiency was measured through composite score of Q12+Q13 (reverse-scored). The measure of resolution time was indirectly represented as respondent-reported mean wait time when using RSA and user-rated adequacy of the technical aspect of RSA.

Statistic	Value	Interpretation
Pearson r	+0.61	Moderate-strong positive correlation
p-value	< 0.001	Statistically significant (α = 0.05)
r^2	0.37	Skill gap explains 37% of resolution time variance
Decision	Reject H0	H2 Supported

Interpretation: Longer resolution times are significantly related to perceived skill deficiency. Technicians who had lower scores pertaining to EV competence were associated with events of RSA which required significantly longer periods to resolve. H2 is accepted

Metric	Finding	Implication
Ran out of charge mid-journey (Q18)	54% Yes	Moderate demand signal
Preference: mobile charge vs. tow (Q19)	43% mobile charge | 57% tow	Majority prefer towing
WTP ₹500 (Q20)	41% respondents	Insufficient to cover costs
WTP ₹1,000 (Q20)	29% respondents	Near break-even only
WTP ₹1,500+ (Q20)	12% respondents	Viable segment but too small
Not willing to pay (Q20)	18% respondents	Zero revenue from 18%
Mobile charging necessary (Q21 mean)	3.74 / 5	Conceptually endorsed, not commercially supported
Feasibility correlation (demand vs. cost gap)	r = -0.58 | p < 0.001	H4 Supported

Interpretation: EV depletion and conceptual support of mobile charging as necessary has experienced 54 and 57 percent adoption by users, respectively, but willing-to-pay is out of step with operational costs by 10 times. WTP majority cluster (₹500) comprises about 30-35 percent of per-deployment cost. The correlation of the system cost expectations with perception of feasibility (r = -0.58) supports the finding that high cost is one of the main obstacles to mobile charging adoption. Accepted: H4 is not commercially viable as a standalone product of RSA in Indian market conditions.

VI. TRIANGULATION OF FINDINGS

Triangulation will be done between three data sources: insights based on qualitative interviews, quantitative survey data, and published literature. The aim is to evaluate convergence, spot contradictions, and enhance the validity of conclusions.

Hypothesis	Interview Insight	Survey Finding	Literature Support	Convergence
H1: Infrastructure	100% of RSA respondents cited charging and towing gaps as primary challenge. Flatbed availability = 23%.	Q9 mean = 2.18; Q11 mean = 4.21; r = -0.68 (significant)	Chakraborty et al. (2019), IEA (2023), Green et al. (2020)	Strong
H2: Skill	Only 14% of technicians HV-trained per et al. All OEM/RSA respondents confirm gap.	Q12 mean = 2.31; Q13 = 2.47; r = +0.61 (significant)	McKinsey (2022), Mohanty et al. (2020), Coffman et al. (2017)	Strong

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VII. PROPOSED EV RSA OPERATIONAL FRAMEWORK FOR INDIA

According to the synthesized results of all the qualitative research, quantitative analysis, and literature survey, this article postulates an elaborate Tier-Based EV RSA Operational Framework (TEROF) to India.

The framework is designed to be:

- Pragmatic, addressing current constraints rather than idealized conditions
- Phased, allowing gradual capability development
- Flexible, applicable across OEM-led, aggregator-led, and insurance-driven RSA models

7.1 Framework Architecture Overview

TEROF has three levels of service delivery capacity, and four pillars of functional core, on the context of conditional criteria of mobile charging deployment.
This layered architecture ensures that RSA providers can progressively build capabilities while maintaining service reliability at each stage of EV ecosystem maturity.

7.2 Tier Classification

Tier	Coverage Area	Capability Level	Response Time Target	Deployment Model
Tier 1 - Advanced	Metro cities (Mumbai, Delhi, Bengaluru, Chennai, Pune, Hyderabad)	Full EV-certified fleet, real-time dispatch, DC fast charge partner network	< 25 minutes	OEM-led or major aggregator
Tier 2 - Standard	State capitals, Tier-2 cities (>500k population)	EV-trained technicians, flatbed deployment, AC charging partner network	< 40 minutes	Insurance RSA, regional aggregator
Tier 3 - Basic	Tier-3 cities, national highways	EV-safe towing, phone-guided assessment, nearest charging station referral	< 60 minutes	Franchise model, OEM helpline coordination

7.3 Pillar 1: EV Technician Certification System

It is suggested to introduce a tiered and mandatory EV RSA technician certification system, which will be based upon the Institute of the Motor Industry (IMI) EV certification system used in the UK, modified to Indian cost and institutional barriers:

- Level 1 - EV Awareness: 2-day training on HV safety basics, PPE needs, do not touch. Cost: ₹3,000-5,000 per technician. Obligatory to all the field RSA staff.
- Level 2 - EV Road Assessment: 5-day trainings with BMS basic diagnostics, charging system evaluation, towing decision guidelines. Cost: ₹8,000-12,000. Prerequisites to all EV RSA deployment technicians.
- Level 3 - EV HV Specialist: 15 days course on adv. battery diagnostics, HV safe intervention system, mobile charging operation. Cost: ₹20,000-30,000.

Tier-1 specialist Technicians required. Delivery partnerships through certification Certification delivered by EV Skill Council of India, ESDM, program based on ITI-linked upgrade, and OEM training academies. The government should subsidize the cost of certification (proposed: 50% subsidy through FAME III or successor scheme) to RSA companies.).

7.4 Pillar 2: Smart Dispatch System (EV-Aware)

The existing RSA dispatch systems need basic improvement to enable EV breakdown management. The proposed Smart Dispatch System (EASDS) is EV-001 integrated with

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- Real-time charging network integration:

API to check charging stations in real-time (of major network operators: Tata Power EV, Statiq, ChargePoint, Ather Grid) - allows dispatchers to check nearest functioning charging station prior to route.

- EV vehicle profile database:

Dispatch platforms should maintain a comprehensive EV-specific database, including parameters such as towing compatibility (e.g., flatbed requirement), HV voltage classification, battery capacity, and known model-specific failure patterns. This enables more informed and context-sensitive decision-making during dispatch.

- Technician competency alignment:

Allocation logic within dispatch systems should prioritize Level 2 or higher certified technicians for EV-related incidents. In cases where proximity becomes critical—such as highway breakdowns—Level 1 technicians may be deployed as an interim response, ensuring a balance between speed and technical capability.

- Predictive ETA and communication transparency:

This is a real time tracking that is shared with customer since the dispatch confirmation, and an automated status update after every 10 minutes. This goes right to the point where the communication breakdown referred to in the qualitative results was found as the black hole.

7.5 Pillar 3: Infrastructure Integration Network

In order to form RSA-Priority Charging (RPC) arrangements, operators of RSA have to enter into formal, contractual relationships with charging network operators:

- Emergency charging reservation:

5 percent top-priority charging stations along highways marked one as being part of the RSA-priority, and provided a slot to tow-delivered EV drivers within 15 minutes.

- Fleet-based charging agreements:

For fleet operators, RSA service packages should include access to designated depot charging facilities as a fallback option. This provides an additional layer of operational reliability, particularly in high-utilization fleet environments.

- Highway charging corridor development:

Charging stations should be located at each 60 km distance along the National Highways, which will be consistent with the existing recommendations by NITI Aayog-with the input of RSA as to the location of this charging station primarily on the basis of data on breakdowns.

7.6 Pillar 4: Tier-Based Service Menu

Service Type	Tier 1	Tier 2	Tier 3
On-site EV diagnosis	Full BMS diagnostic scan	Basic fault code reading	Phone-guided self-check
Battery depletion response	Mobile charge or tow-to-fast-charge	Tow to nearest AC charger	Tow to nearest available point
HV fault handling	Level 3 specialist dispatch	Level 2 + OEM helpline	Do-not-touch + tow
Towing equipment	Flatbed dedicated fleet	Flatbed within 15 min radius	Flatbed on-call (60+ min)
Response time SLA	< 25 min (80% calls)	< 40 min (75% calls)	< 60 min (70% calls)
Customer communication	Real-time app tracking	15-min automated SMS updates	Manual call-back every 30 min

7.7 Mobile Charging Deployment Conditions (Conditional Feasibility)

Based on the empirical findings of this study, mobile EV charging is recommended for deployment ONLY when ALL of the following conditions are met:

Condition	Threshold	Rationale
EV Density	> 15% of vehicles in the service zone	Below this, call frequency cannot sustain unit economics
Daily Deployment Rate	> 3 deployments per mobile unit per day	Minimum to approach break-even per Muratori et al. (2019)
Service Model	OEM warranty bundle OR fleet subscription	Willingness-to-pay gap requires cross-subsidy
Route Predictability	Fixed-route fleet or event-based context	Predictable demand enables pre-positioning
Unit Cost Recovery	Per-deployment revenue > ₹1,200	Minimum operational cost coverage
Energy Source	Renewable or grid-charged overnight	Environmental integrity and cost control

In all other cases where mobile charging fails to comply with these conditions, Flatbed Tow-to-Charge is the recommended default course of action: a special flatbed vehicle pulls the EV to the closest verified operational charging station, and a loaner vehicle or ride-hail credit is offered to the customer at the time of the charging session. This is an operationally simpler model, more scalable, and gives more high levels of customer satisfaction as compared to a failed mobile charging experiment.

VIII. RECOMMENDATIONS

The findings of this study suggest that strengthening Electric Vehicle (EV) Roadside Assistance (RSA) in India requires coordinated efforts from charging network operators, OEMs, RSA providers, and policymakers.

For charging network operators, it is recommended to establish RSA-priority charging by collaborating with leading RSA providers to reserve priority charging slots and integrate shared uptime reporting through application programming interfaces (APIs). Network operators should also improve the reliability of charging infrastructure by targeting at least 90% uptime for highway-facing charging stations and providing real-time charger status information that can be seamlessly integrated into RSA platforms to support faster service delivery.

For Original Equipment Manufacturers (OEMs), authorized RSA partners should be required to obtain TEROF Level 2 certification within 18 months of partnership initiation to ensure consistent service quality. OEMs should leverage connected vehicle technologies by integrating RSA dispatch into in-

vehicle telematics, enabling proactive assistance when a vehicle's battery state of charge falls below critical thresholds (e.g., less than 10%) before a complete breakdown occurs. To improve service availability in underserved regions, OEMs should collaborate in creating shared RSA cost-sharing pools that jointly fund highway-based RSA infrastructure. Furthermore, warranty programs should be redesigned to include clearly defined RSA response time service-level agreements (SLAs), thereby strengthening customer confidence and enhancing the perceived value of after-sales support.

For RSA providers, expanding the availability of flatbed tow trucks should be a strategic priority, with a target of achieving approximately 40% fleet penetration in metropolitan regions within the next 24 months. Investments should also be made in intelligent EV-specific dispatch systems that integrate charging network APIs and fleet management platforms to improve routing efficiency and reduce response times. Service providers should establish dedicated EV specialist teams by ensuring that 15–20% of metropolitan technicians possess Level 2 or higher EV certification and are available around the clock. Additionally, pilot programs offering subscription-based mobile charging services should be introduced on high-EV-density metropolitan routes to evaluate their operational and commercial feasibility.

For policymakers, the development of standardized EV RSA competency requirements is essential.

Regulatory authorities should require RSA companies to maintain a minimum ratio of one Level 2 certified EV technician for every five technicians as part of licensing and compliance requirements. Government incentive schemes, such as future iterations of the FAME program, should be expanded to support investments in flatbed tow trucks, EV diagnostic equipment, technician certification, and other RSA infrastructure. Publicly subsidized charging infrastructure should also be strategically located along highways and high-breakdown corridors to improve roadside assistance accessibility. Finally, an inter-ministerial EV RSA working group, involving agencies such as the Ministry of Road Transport and Highways (MoRTH), Ministry of Power (MoP), and Department for Promotion of Industry and Internal Trade (DPIIT), should be established to develop a unified national EV RSA policy framework with clearly defined implementation milestones and accountability mechanisms.

IX. CONCLUSION

This paper aimed to focus on the analysis of one of the most crucial aspects of the Indian electric vehicle change that have previously been little explored: the operational maturity of the roadside assistance system to provide services to EV users. The study has resulted in empirically based responses to four hypotheses and a viable operational model of the industry through 12 rigorous in-depth interviews and a 118 respondent quantitative survey.

Its results are clear: the ecosystem of EV RSA in India is structurally inadequate to the requirements that it is forced to meet. The main systemic bottleneck is infrastructure gaps ($r = -0.68$ with RSA efficiency), followed by the lack of technician skills ($r = +0.61$ with resolution time), the service delivery failures, the response time, the most important customer satisfaction, and mobile EV charging, which exists only in theory, is economically inappropriate in the context of the Indian market at the current stage.

The implications of these findings go beyond the RSA industry. Without an after-sales service ecosystem, where RSA is the most visible emergency element, the EV uptake impetus created by the government policy and OEM investments will have an experience gap in the real-life that undermines consumer trust. The solutions to the challenges of EV RSA are not an incidental operational issue at the national level: EV RSA is an enabler of the EV transition in India.

The Tier-Based EV RSA Operational Framework (TEROF) presented in this paper will provide a practical, step-by-step, and workable solution to bridging the existing gap in capabilities. It is built to serve the diverse geographic, infrastructure maturity levels of India, and business model ecosystems-OEM led premium RSA in metro corridors to franchise based simple cover on national highways.

This paper is limited in scope by the main thesis of this paper which is that India can not create a global EV-based system on a breakdown-assistance system of the World War I era. These investments needed-training of technicians, modernization of equipment, intelligent dispatch technology, and integration of infrastructure are quite small when compared to the costs being already incurred by OEMs, government and consumers on EV transition. The payoffs in terms of customer trust, trust in its ecosystem, and EV acceptance are high.

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